GROUND-WATER LEVELS, FLOW, AND QUALITY IN NORTHWESTERN ELKHART COUNTY, INDIANA, 1980-89

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 91-4053

Prepared in cooperation with the

ELKHART WATER WORKS

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Indianapolis, Indiana

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U.S. GEOLOGICAL SURVEY

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CONVERSION FACTORS, VERTICAL DATUM, AND ABBREVIATED WATER-QUALITY UNITS

Multiply	By	To obtain
acre	0.4047	hectare
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
foot (ft)	0.3048	meter
foot per day (ft/d)	0.3048	meter per day
foot per mile (ft/mi)	0.1894	meter per kilometer
inch (in.)	2.54	centimeter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.59	square kilometer

Temperature in degrees Celsius (°C) can be converted to degrees Fahrenheit (°F) by the following equation:

$$°F = (1.8 \times °C) + 32$$

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929--a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

The following terms and abbreviations also are used in this report:

mg/L	Milligram per liter
pH	Negative log base -10 of the hydrogen ion activity, in moles per liter
µS/cm	Microsiemen per centimeter at 25° Celsius
mL	Milliliter

GROUND-WATER LEVELS, FLOW, AND QUALITY IN NORTHWESTERN ELKHART COUNTY, INDIANA, 1980-89

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ABSTRACT

Ground-water data were collected in northwestern Elkhart County, Indiana, from 1980 through 1989 to monitor hydrologic conditions and to provide information necessary for water-resources managers to evaluate the ground-water resources in this area. The area of study includes a closed industrial landfill and several areas of industrial and municipal pumping. Water levels were measured twice a year in 68 wells, and water samples were collected once a year from 32 wells. The wells were screened in unconsolidated glacial-outwash deposits--primarily sand and gravel.

During the study, measured ground-water levels ranged from about 6 feet above ground level to about 29 feet below ground level. The average depth to water for all wells was 10 feet, and the average water-level fluctuation for the entire study period was 4.8 feet. In the study area, ground water flows toward the St. Joseph River. Water levels near the river are higher than the stage of the river, indicating that ground water is discharged to the river.

Water samples were collected and analyzed to determine concentrations of dissolved bromide. Onsite measurements of specific conductance, pH, water temperature, and concentrations of dissolved oxygen and alkalinity were made at the time of sampling. The water samples had a median specific conductance of 516 microsiemens per centimeter at 25 degrees Celsius, a median ph of 7.6, a median alkalinity of 216 milligrams per liter (as calcium carbonate), and a median dissolved-bromide concentration of 0.08 milligrams per liter.

Water-quality data were grouped according to the depth and position of the wells in the flow system with respect to the closed industrial landfill. Shallow wells are those less than 100 feet deep; deep wells are those more than 100 feet deep. Comparison among groups indicates that water from shallow wells downgradient from the landfill had larger values of specific conductance, larger concentrations of alkalinity and dissolved bromide, and smaller values of pH than did water from shallow wells upgradient from the landfill and water from deep wells throughout the study area.

Concentrations of dissolved bromide were used to estimate the extent of the landfill's effect on ground-water quality by plotting and contouring the concentration values on maps and hydrogeologic sections. The maps show a plume of bromide extending south of the landfill along the direction of ground-water flow. The hydrogeologic sections indicate that water containing bromide is moving vertically downward in the unconfined aquifer beneath and downgradient from the landfill. Maps and sections for different time periods were compared to determine how the distribution of bromide was changing. Although dissolved-bromide concentrations in water from individual wells were variable, the distribution of dissolved bromide did not change substantially during the study period.

The time of peak dissolved-bromide concentrations in water from shallow wells downgradient from the landfill was used to estimate a rate of horizontal flow of water in the unconfined aquifer. The average rate of flow between shallow wells downgradient from the landfill was estimated to be 1.2 feet per day. This rate is within the range of values for ground-water flow calculated according to Darcy's law.

INTRODUCTION

Background

The city of Elkhart, Indiana, obtains its public water supply from well fields screened in a thick sand and gravel aquifer. Water quality in this aquifer has changed in some areas in and near Elkhart by disposal of liquid and solid wastes. Volatile organic compounds have been detected in the ground water near an industrial park in east Elkhart and at the city's Main Street well field (Imbrigiotta and Martin, 1981, p. 2). Donahue and Associates, Inc. (1990, p. 2-2) reported that leachate from a closed industrial landfill in northwestern Elkhart County has penetrated the shallow unconfined aquifer and increased the concentration of metals and volatile organic compounds in the ground water beneath and downgradient from the landfill.

In 1977, the U.S. Geological Survey (USGS), in cooperation with the Indiana Department of Natural Resources and the Elkhart Water Works, began a study of the ground water in northwestern Elkhart County (Imbrigiotta and Martin, 1981). At the end of that study, a ground-water monitoring program was established to measure water levels and collect water-quality samples from selected wells in the study area. The monitoring program was designed to provide information that could be used to evaluate if changes were occurring in the ground-water-flow system which were caused by industrial and municipal pumping and what the long-term effects of a closed industrial landfill were on ground-water quality in the area. The USGS, in cooperation with the Elkhart Water Works, began the monitoring program in 1982.

Purpose and Scope

This report presents the results of the ground-water monitoring program in northwestern Elkhart County along with previously unpublished data from the study by Imbrigiotta and Martin (1981). Data collected from 1980 through 1989 are included. Water levels from 68 wells and water-quality data from 32 wells are presented and discussed. Statistical summaries of the data are included. Water-level data are listed in tables and shown on selected maps and hydrographs. Water-quality data are listed in tables and shown on selected maps, hydrogeologic sections, and graphs. The distribution of water containing dissolved bromide is used to delineate the approximate boundaries of a leachate plume near the closed industrial landfill. Changes in dissolved-bromide concentrations during the study are discussed, and the rate of flow of ground water is estimated from the time of peak bromide concentrations in water from wells downgradient from the landfill.

Study-Area Characteristics

The following brief descriptions are provided to give the reader an overview of the important characteristics of the study area. Those readers who want more detailed descriptions are referred to the report by Imbrigiotta and Martin (1981) and to the other publications that are referenced in this report.

Location and Description

The original study area investigated by Imbrigiotta and Martin (1981) included 120 mi^2 in northwestern Elkhart County in north-central Indiana (fig. 1). The study area of the ground-water monitoring program includes the northwestern part of the original area of which a 20-mi^2 area on the northwestern side of the city of Elkhart is of primary interest (fig. 1).

Elkhart is the largest city in northwestern Elkhart County and includes an area of about 17 mi^2. The population of Elkhart was 43,100 in 1980, and the population of the city urbanized area was 68,000 (Elkhart Chamber of Commerce, 1990). Industrial activities in and near Elkhart include the manufacture of pharmaceuticals, recreational vehicles, mobile homes, and band instruments. Agriculture is the predominant land use in Elkhart County and includes dairy, poultry, and fruit farming (Imbrigiotta and Martin, 1981, p. 4).

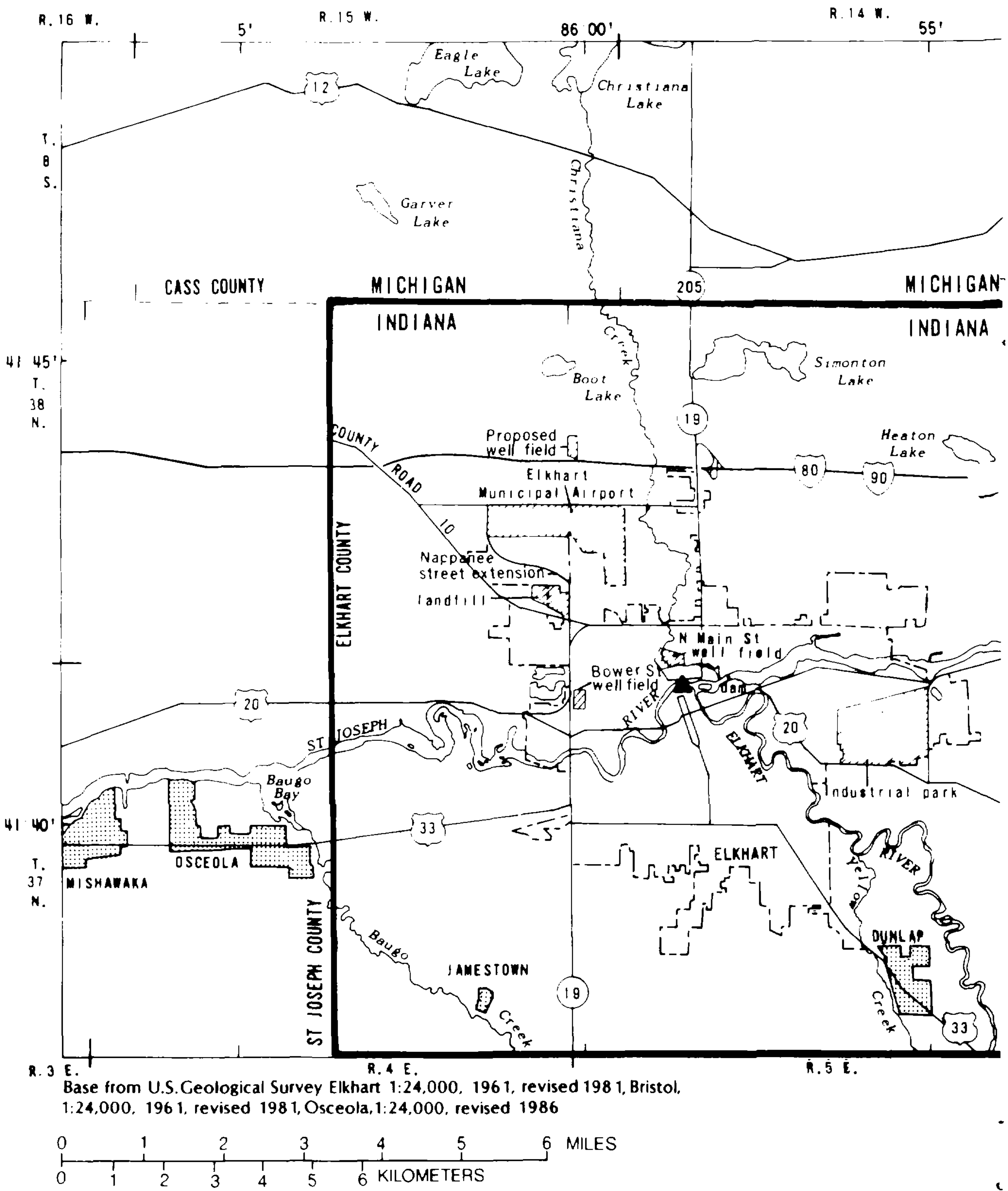
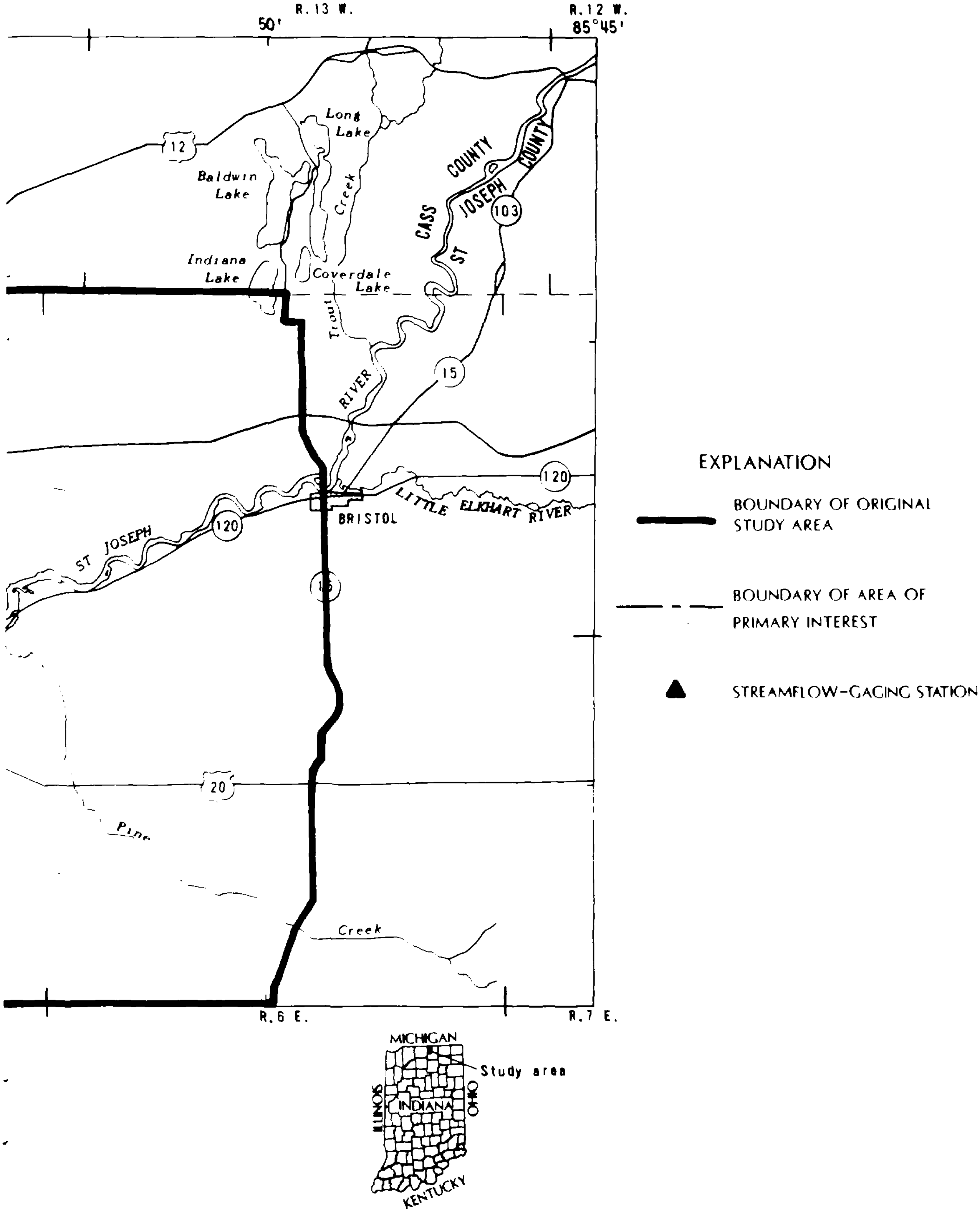


Figure 1.–Location of the original study area of Imbrigiotta and Martin (1981)



and the area of primary interest for the Elkhart ground-water monitoring program.

The Himco landfill, which is generally referred to as the "landfill" in this report, is in the northwestern part of Elkhart near the intersection of County Road 10 and the northern extension of Nappanee Street (fig. 1). The filled area occupies approximately 30 acres that were originally a swamp. During 1960-76, the landfill was used primarily to dispose of commercial and industrial wastes. Only small volumes of domestic wastes were disposed of at the site. Calcium sulfate, used in the manufacture of pharmaceuticals, was disposed of in large quantities at the site and was used as a substrate for the final cover (Donahue and Associates, Inc., 1990, p. 2-1). At the time of closing, the elevation of the surface of the landfill ranged from 5 to 15 ft above the original ground level.

Physiography and Climate

The study area is part of the St. Joseph River basin that drains the region from east to west. The basin is part of the Northern Moraine and Lake Region described by Malott (1922, p. 112) and Schneider (1966, p. 50). The land surface is nearly flat near the St. Joseph River and grades to rolling topography in the northern and southern parts of the original study area. Land-surface altitudes range from about 740 to 950 ft above sea level.

Elkhart County has a temperate climate, with a mean annual temperature of 9.8 °C and a mean annual precipitation of 33.7 in. For 1951-80, the mean monthly temperature varied from -4.8 °C in January to 22.7 °C in July, and the mean monthly precipitation varied from 1.58 in. in February to 3.66 in. in August (National Oceanic and Atmospheric Administration, 1982).

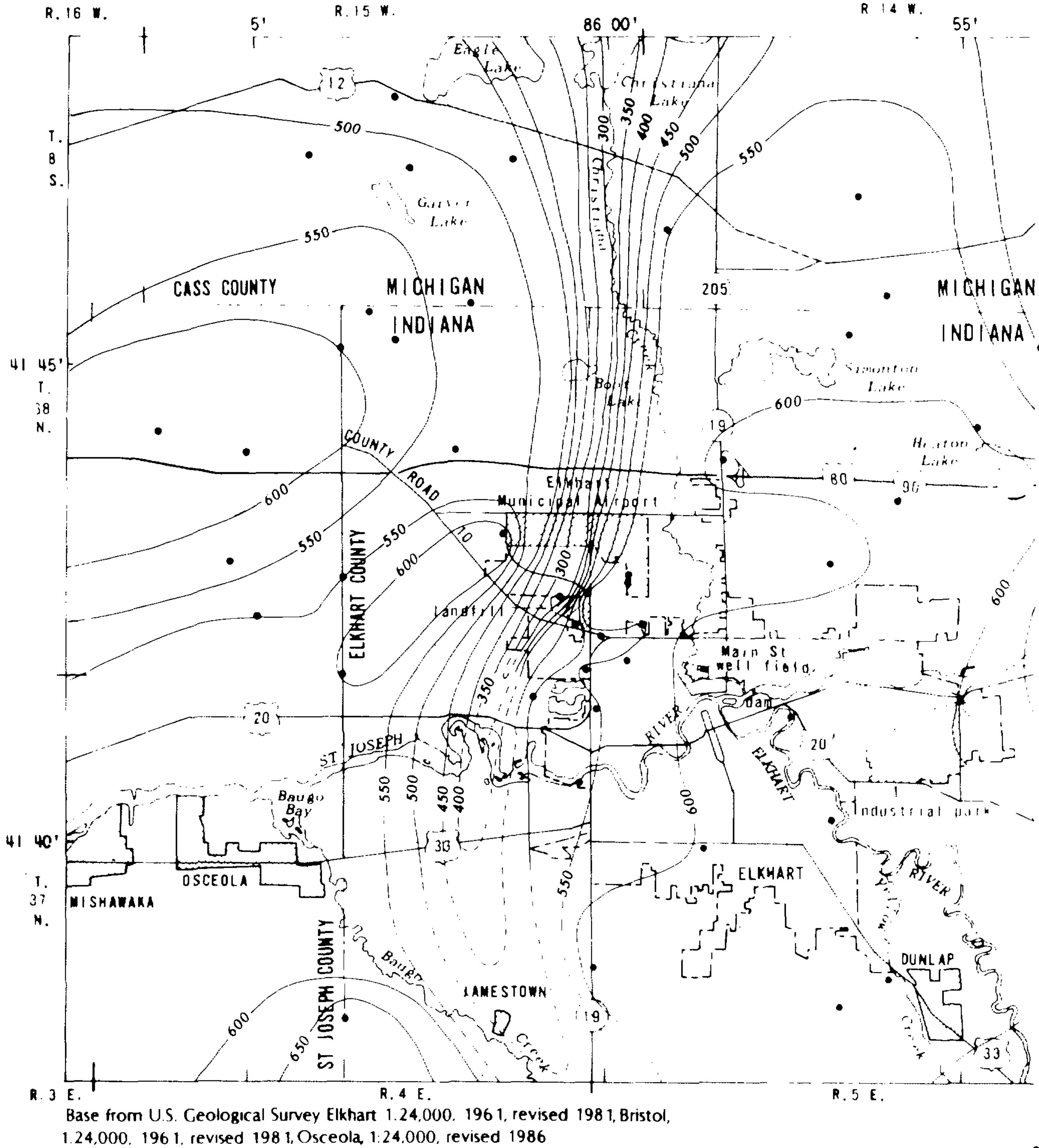
Geology

The study area is underlain by shale bedrock of Devonian and Mississippian age (Johnson and Keller, 1972). The bedrock surface ranges from about 300 to 650 ft above sea level (fig. 2). Structurally, the bedrock is part of the Michigan Basin and dips about 30 ft/mi to the northeast (Indiana Department of Natural Resources, 1987, p. 15). The most prominent feature of the bedrock surface is a preglacial valley trending from south to north through the west-central part of the study area. Overlying the bedrock are unconsolidated deposits of glacial origin classified primarily as valley-train-outwash deposits (fig. 3). These deposits range in thickness from about 85 to 500 ft and contain thick layers of sand and gravel with interbedded silt and clay (Imbrigiotta and Martin, 1981, p. 1).

Hydrology

The St. Joseph River, a tributary to Lake Michigan, is the principal surface-water feature in the region. Other streams include the Elkhart River, Christiana Creek, Pine Creek, and Baugo Creek. All surficial drainage flows to the river or its tributaries and leaves the study area at the western boundary. The average discharge of the St. Joseph River at Elkhart (fig. 1) is 3,204 ft^3/s for the 41-year period from 1947 through 1988. The maximum instantaneous discharge during that period was 18,000 ft^3/s in February 1985, and the minimum daily discharge was 336 ft^3/s in August 1964 (Glatfelter and others, 1989, p. 202). The drainage area of the St. Joseph River at Elkhart is 3,370 mi^2.

The principal aquifers are contained in the unconsolidated glacial-outwash deposits. Throughout most of northwestern Elkhart County there are two layers of sand and gravel separated by a layer of silt and clay that averages 20 ft in thickness (Imbrigiotta and Martin, 1981, p. 15). Where the silt and clay layer is present, it divides the glacial deposits into an upper unconfined aquifer and a lower confined aquifer. The confining layer is absent near the landfill. The calculated average horizontal hydraulic conductivity of the aquifer materials in the study area is 80 ft/d in sand and 400 ft/d in sand and gravel (Imbrigiotta and Martin, 1981, p. 24). The horizontal hydraulic conductivity of the confining layer is assumed to be small, about 0.1 ft/d. Vertical hydraulic conductivities were not directly determined for the aquifers and confining layer; however, a ratio of vertical to horizontal hydraulic conductivity of 1:10 was determined by Meyer and others (1975, p. 19) for an outwash-aquifer system similar to that underlying northwestern Elkhart County. Ground-water flow is primarily horizontal and toward the St. Joseph River and smaller streams. Water levels in wells near the St. Joseph River are as much as 6 ft higher than the river stage, indicating that ground water discharges to the river.

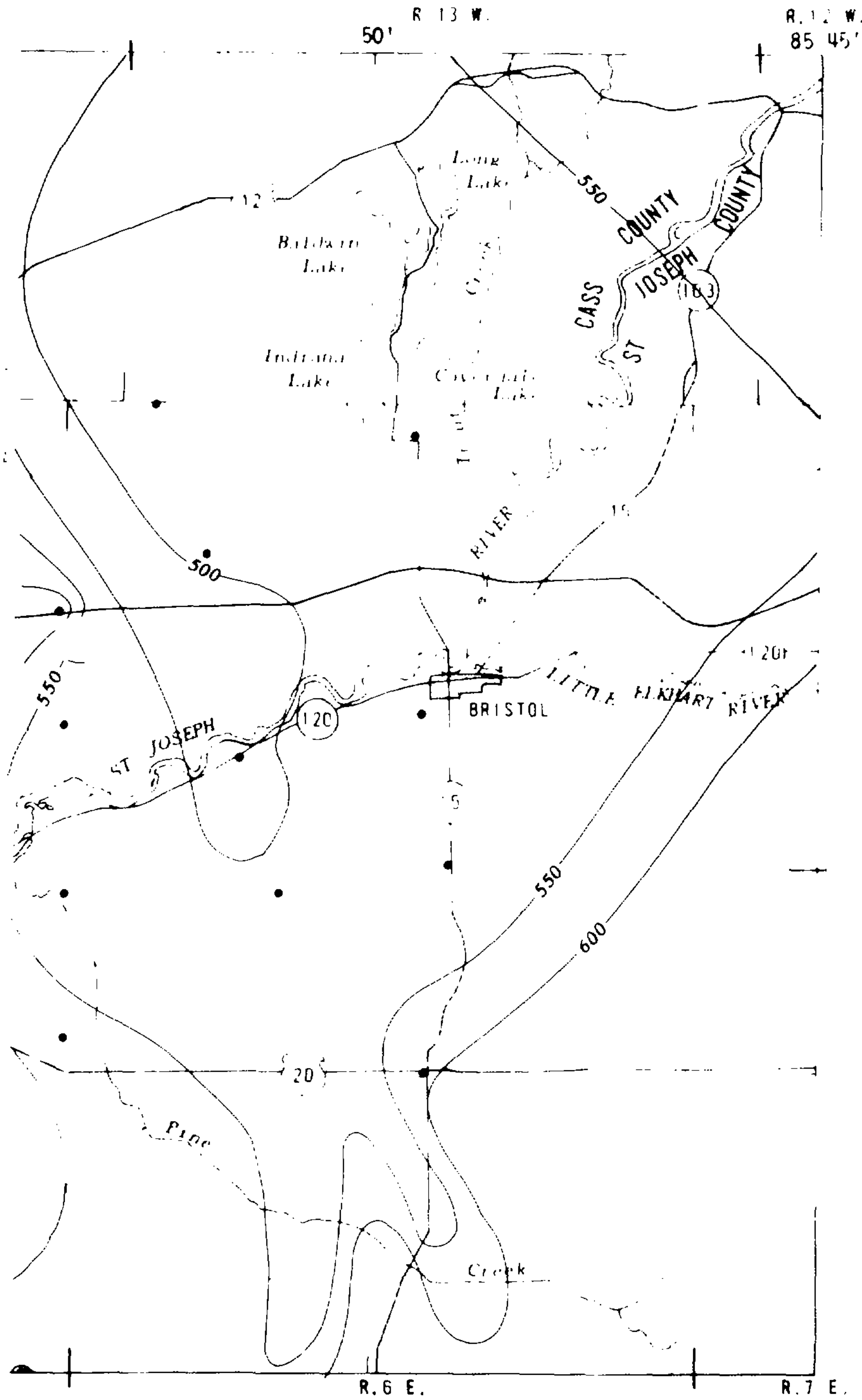


Base from U.S. Geological Survey Elkhart 1:24,000, 1961, revised 1981, Bristol, 1:24,000, 1961, revised 1981, Osceola, 1:24,000, revised 1986

0 1 2 3 4 5 6 MILES

0 1 2 3 4 5 6 KILOMETERS

Figure 2.--Bedrock topography in parts of Elkhart and St. Joseph Counties,



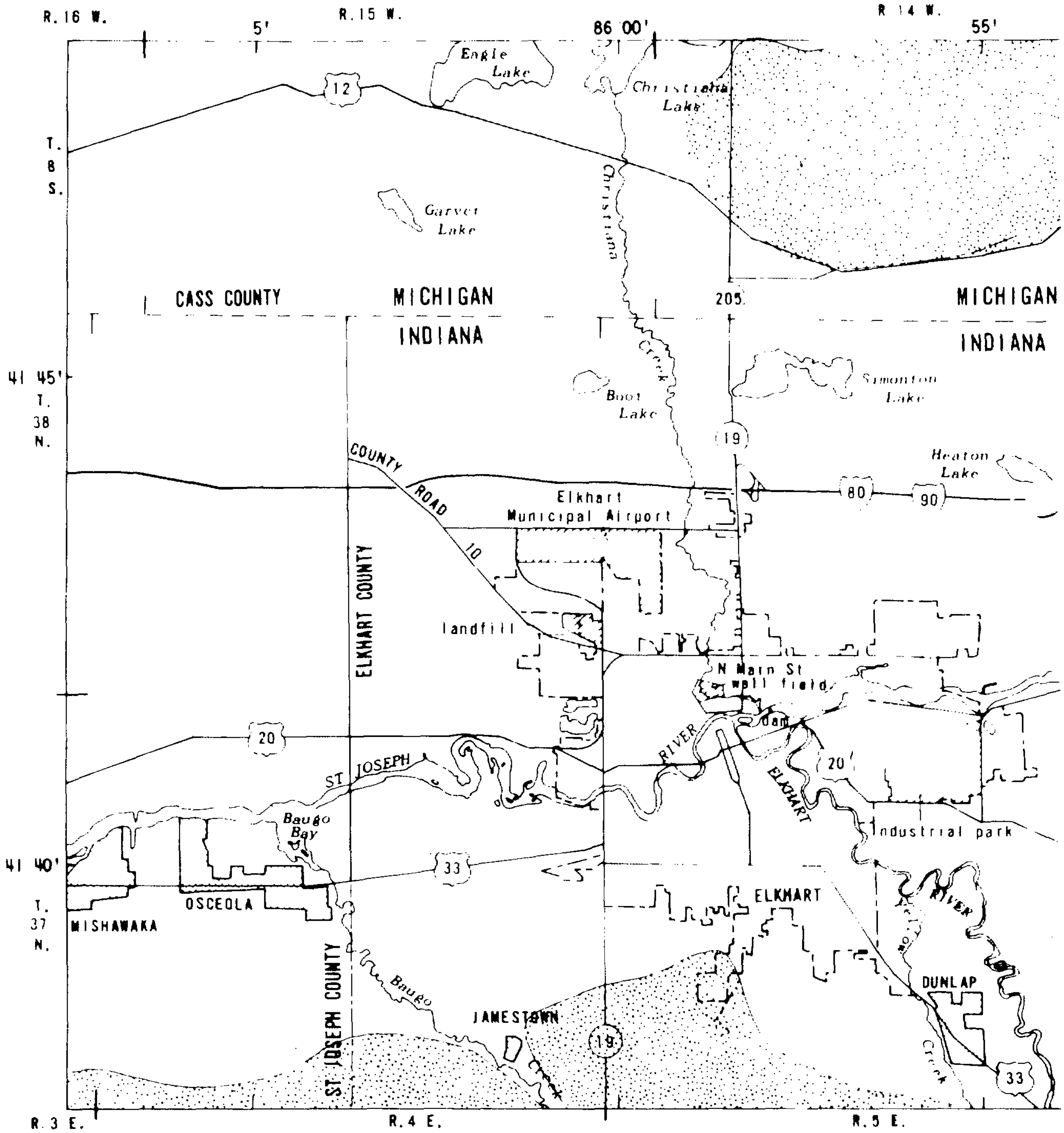
Bedrock topography modified from G.H. Johnson and S.J. Keller (1972)

EXPLANATION

—— 500 - - - BEDROCK CONTOUR--Shows altitude of bedrock surface. Dashed where approximately located Contour interval 50 feet. Datum is sea level

• DATA POINT

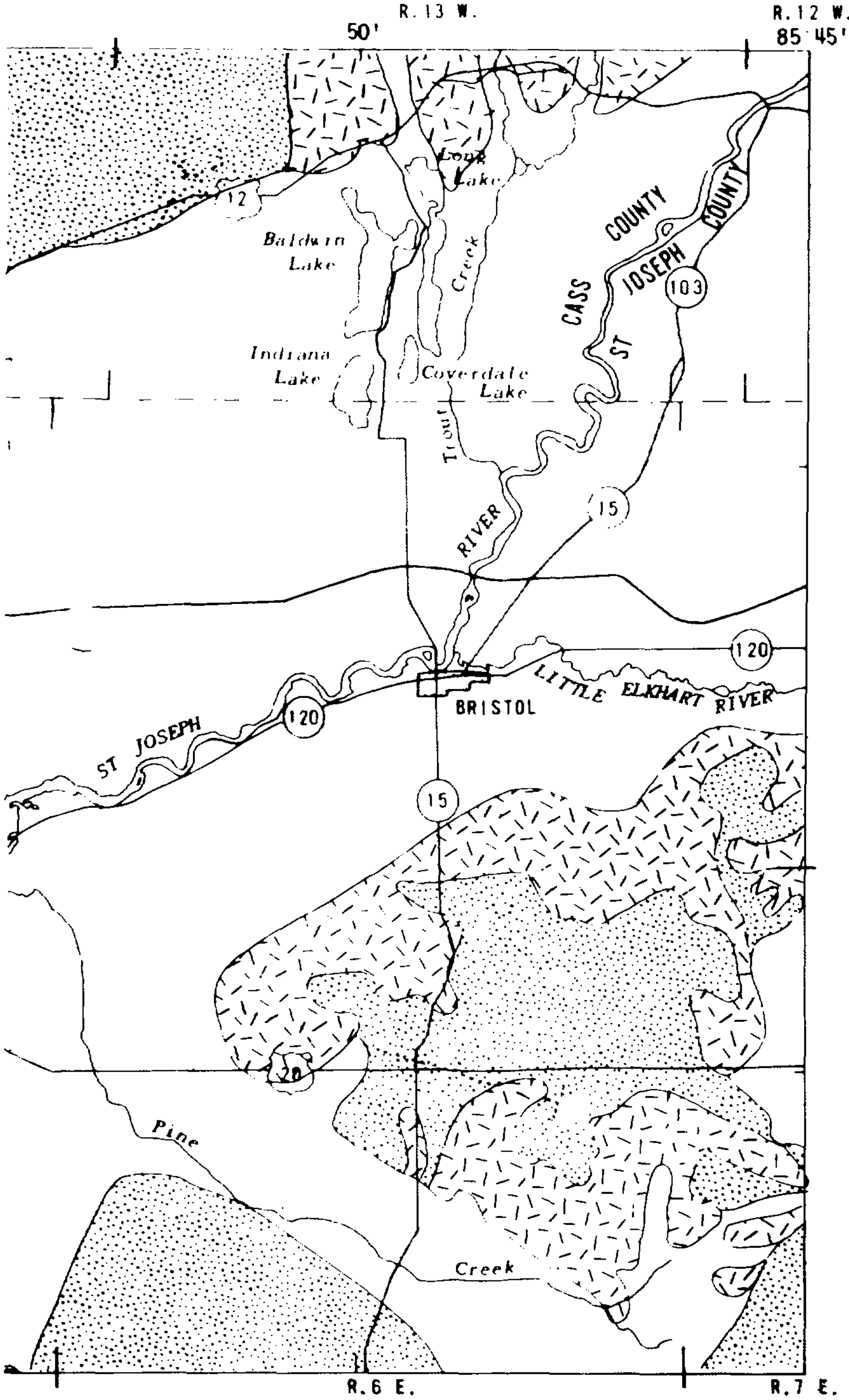
Ind., and Cass and St. Joseph Counties, Mich.



Base from U.S.Geological Survey Elkhart 1:24,000, 1961, revised 1981, Bristol, 1:24,000, 1961, revised 1981, Osceola, 1:24,000, revised 1986

0 1 2 3 4 5 6 MILES
0 1 2 3 4 5 6 KILOMETERS

Figure 3.--Surficial geology in parts of Elkhart and St. Joseph



Geology modified from G.H. Johnson and S.J. Keller (1972)

EXPLANATION

ICE-CONTACT STRATIFIED DRIFT-- Mostly silt with some sand and gravel

VALLEY-TRAIN OUTWASH DEPOSITS-- Sand and gravel

GROUND-MORAINE DEPOSITS-- Till

Counties, Ind., and Cass and St. Joseph Counties, Mich.

METHODS OF INVESTIGATION

Data-Collection Network

Ground-water levels were measured at 68 wells, and water samples were collected from 32 wells. The locations of the wells are shown on figures 4 and 5, and a complete description of the wells in the Elkhart monitoring network is listed in table 1. The wells were part of the original network of approximately 170 wells installed during 1977-79 for the previous hydrologic investigation by Imbrigiotta and Martin (1981). The well-numbering system from that investigation was retained for this study. The wells are divided into three groups: (1) county wells, (2) landfill wells, and (3) river wells. County wells are located throughout the study area and are designated by site numbers (figs. 4 and 5), which in table 1 can be followed by an S or a D, signifying that the wells are shallow or deep in relation to each other. County wells have 2-in. nominal inside-diameter casings and are constructed of black steel. They were installed by either auger or mud-rotary methods to depths ranging from about 12 to 214 ft (table 1). Wells located near the landfill are designated by site letters A through Q (fig. 5) followed by a single-digit number in table 1. Landfill wells have either 2-in. or 5-in. nominal inside-diameter casings. Casing materials may be polyvinyl chloride, galvanized steel, or black steel. The well depths range from about 12 to 342 ft (table 1). Wells also are located near the St. Joseph River or Christiana Creek (figs. 4 and 5). Wells near the rivers are designated by the letter R followed by a one- or two-digit number. These wells have 2-in. nominal inside-diameter casings and are constructed of black steel. Well depths range from about 20 to 24 ft.

Water-Level Measurements

Elkhart Water Works employees measured water levels in the monitoring wells twice a year in the spring and fall. Measurements were made by means of an electrical water-level indicator. The depth to water in each well was referenced to a measuring point at the top of the well. Measuring-point altitudes are referenced to sea level and were determined by leveling from known altitudes during the previous study.

The wells were maintained by the Elkhart Water Works. Several of the wells were damaged during the study, and the measuring points were repaired as nearly as possible to their original altitudes. Elkhart Water Works employees also did slug tests in each well once a year to determine if the well was open to the aquifer. Wells that were plugged were redeveloped by jetting with compressed air.

Water-Quality Samples

Water-quality samples were collected once a year, generally in late summer (July and August), by Elkhart Water Works and USGS employees. The sampling procedure was the same for all wells and is summarized below:

(1) Water levels were measured with a steel tape and chalk prior to sampling each well. The water level was used with the well depth and casing inside diameter to calculate the volume of water in the well.

(2) The wells were pumped by means of one of three types of pumps: (1) submersible, (2) centrifugal, or (3) peristaltic. The type of pump used depended on the depth to water, the volume of water in the well, and the casing diameter. The pumping rate was measured to determine the time necessary to evacuate the volume of water in the well.

(3) Onsite measurements of specific conductance, pH, water temperature, and dissolved oxygen were made with a four-parameter multiprobe instrument. The measuring-probe sonde was placed in a flow chamber at the surface to make the measurements. Well water was pumped into the bottom of the flow chamber, up past the probes, and out the top of the flow chamber. The instrument was calibrated each day with prescribed standards and was recalibrated during sampling if problems were noticed.

(4) To ensure that the water sample was representative of water in the aquifer, the wells were pumped until a volume of water equal to at least three casing volumes was removed from the well before the sample was collected. Specific-conductance measurements were made every 5 minutes during pumping until three successive measurements differed by less than 10 µS/cm.

(5) Samples were collected after the evacuation and stabilization criteria were met. Samples for dissolved bromide and field alkalinity were collected by use of a peristaltic pump. The bromide sample bottle was rinsed with sample water, and the sample was filtered through a 0.45-micrometer membrane filter. Bromide samples were chilled for storage before delivery to the laboratory.

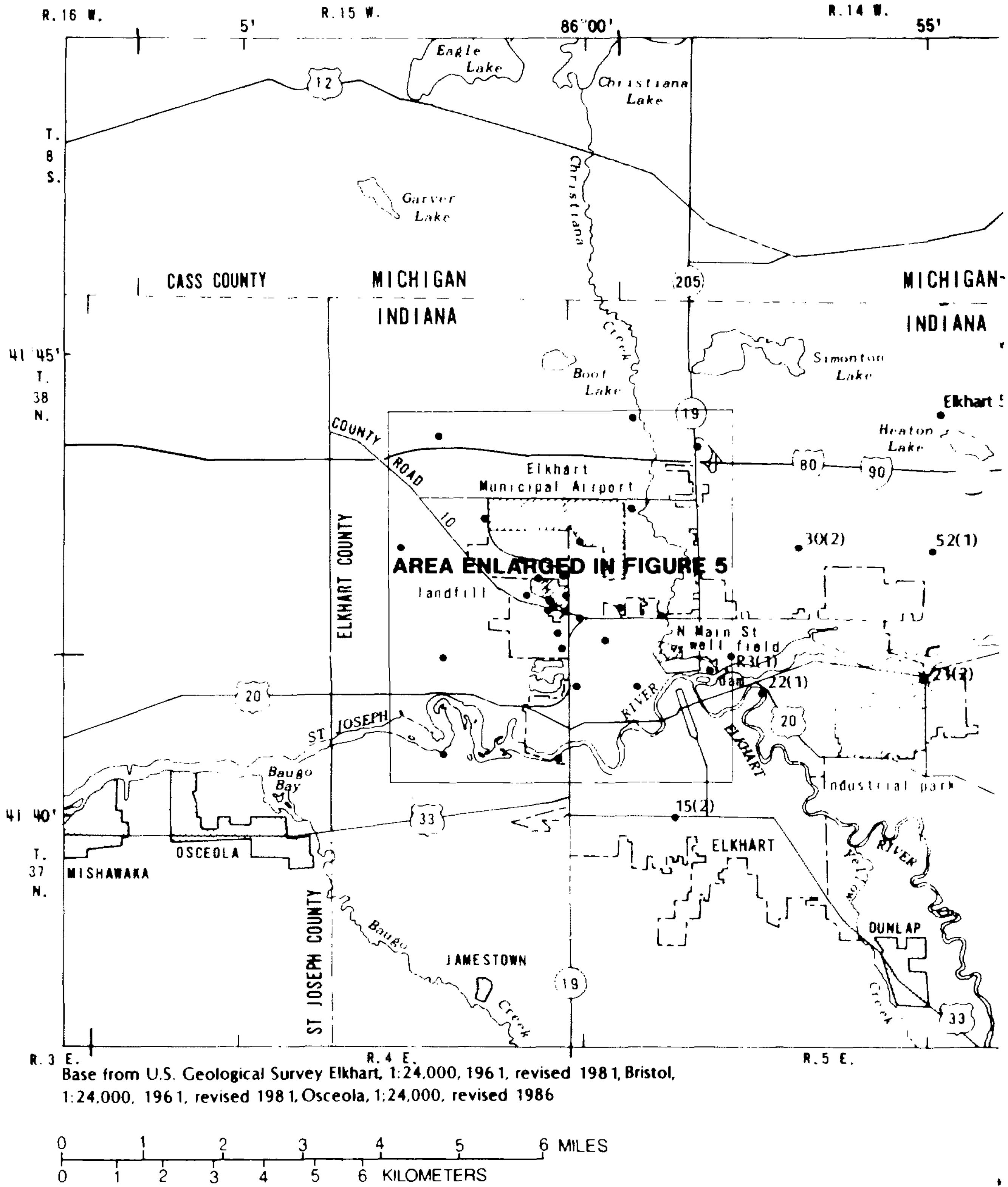
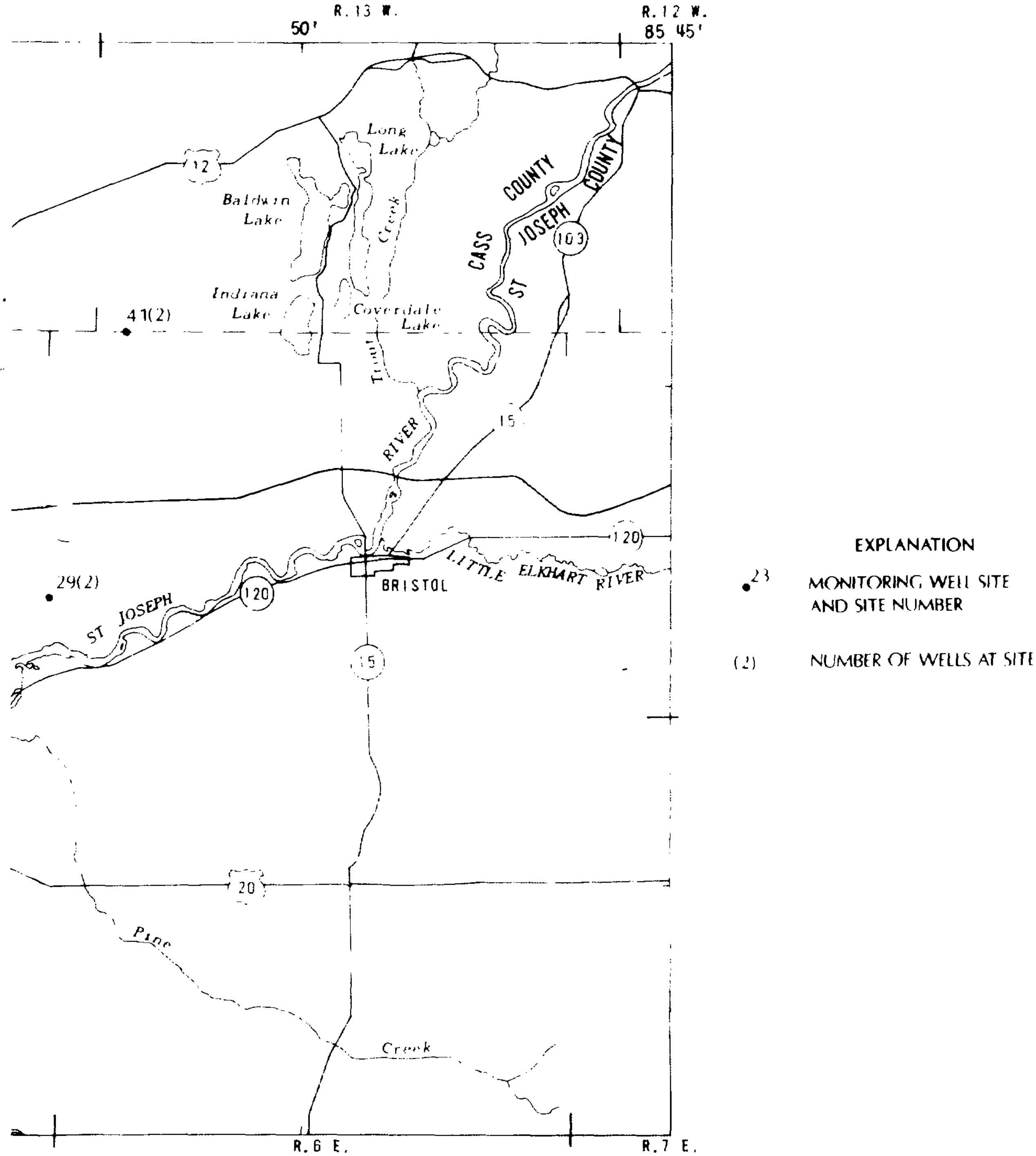
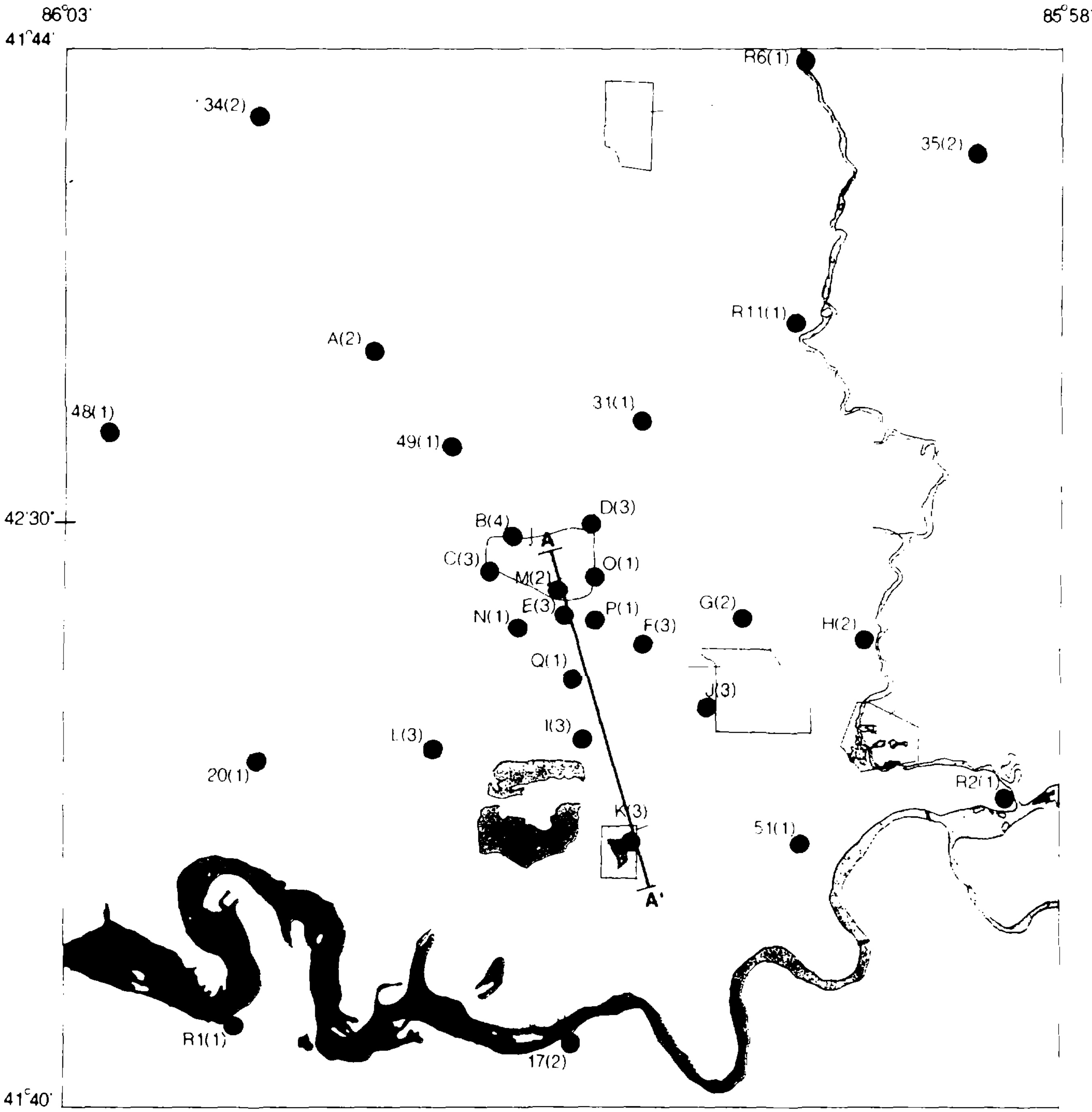


Figure 4.--Location of monitoring wells in the original study

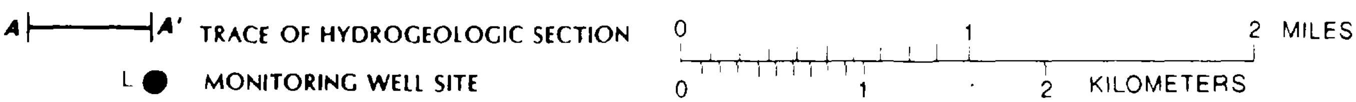


area retained for the Elkhart ground-water monitoring program.



Base from U.S. Geological Survey Elkhart 1:24,000, 1961, revised 1981, and Osceola 1:24,000, 1969, revised 1980

EXPLANATION



TRACE OF HYDROGEOLOGIC SECTION

MONITORING WELL SITE AND SITE DESIGNATION

(4) NUMBER OF WELLS AT SITE

Figure 5.--Location of monitoring wells in the area of primary interest and trace of hydrogeologic section A-A'.

Table 1.--Description of wells in the Elkhart monitoring network

Well number	Latitude[1]	Longitude[1]	Date installed	Method of drilling[2]	Well depth (feet)	Screen length (feet)	Casing diameter (inches)	Casing material[3]	Aquifer type[4]
				County wells					
15S	41°39'54"	85°58'36"	10/06/77	A	23.9	2.5	2	BS	U
15D	41°39'54"	85°58'36"	11/28/77	R	151.0	4.0	2	BS	U[5]
17S	41°40'38"	86°00'20"	10/06/77	A	23.8	2.5	2	BS	U
17D	41°40'38"	86°00'20"	10/19/77	R	173.0	5.0	2	BS	U[5]
20	41°41'42"	86°01'54"	09/28/77	A	24.1	2.5	2	BS	U
22	41°41'30"	85°55'05"	09/14/78	A	11.7	2.5	2	BS	U
23S	41°41'29"	85°55'05"	11/01/77	A	24.3	2.5	2	BS	U
23D	41°41'29"	85°55'05"	11/15/78	R	140.0	4.0	2	BS	C
29S	41°42'58"	85°53'18"	10/26/77	A	24.1	2.5	2	BS	U
29D	41°42'58"	85°53'18"	11/15/78	R	130.0	4.0	2	BS	C
30S	41°43'01"	85°56'46"	10/14/77	A	24.0	2.5	2	BS	U
30D	41°43'01"	85°56'46"	11/14/78	R	172.0	4.0	2	BS	U[5]
31	41°42'59"	86°00'03"	09/29/77	A	26.2	2.5	2	BS	U
34S	41°44'08"	86°01'57"	10/05/77	A	24.1	2.5	2	BS	U
34D	41°44'08"	86°01'57"	10/18/77	R	189.0	5.0	2	BS	C
35S	41°44'01"	85°58'22"	11/01/77	A	24.1	2.5	2	BS	U
35D	41°44'01"	85°58'22"	10/20/77	R	131.0	5.0	2	BS	C
41S	41°45'32"	85°52'16"	10/27/77	A	24.0	2.5	2	BS	U
41D	41°45'32"	85°52'16"	11/16/78	R	214.0	4.0	2	BS	C
48	41°42'56"	86°20'40"	09/30/77	A	24.1	2.5	2	BS	U
49	41°42'53"	86°00'48"	09/27/77	A	24.6	3.0	2	BS	U
51	41°41'25"	85°59'11"	09/30/77	A	24.2	2.5	2	BS	U
52	41°42'53"	85°54'49"	11/08/77	A	24.0	2.5	2	BS	U
				Wells near the landfill					
A1	41°42'16"	86°01'23"	10/04/77	R	135.0	10.0	5	PVC	U[5]
A2	41°42'16"	86°01'23"	10/13/77	A	13.3	10.0	2	BS	U
B1	41°42'35"	86°00'37"	10/06/77	R	473.0	6.0	5	PVC	U[5]
B2	41°42'35"	86°00'37"	11/03/77	A	11.9	10.0	2	BS	U
B3	41°42'35"	86°00'37"	10/17/77	R	135.0	10.0	5	PVC	U[5]
B4	41°42'35"	86°00'37"	10/07/77	R	173.0	5.0	5	PVC	C
C1	41°42'25"	86°00'48"	10/04/77	R	342.0	5.0	5	PVC	U[5]
C3	41°42'25"	86°00'48"	10/05/77	R	197.0	5.0	5	PVC	U[5]
C4	41°42'25"	86°00'48"	10/05/77	R	130.0	10.0	5	PVC	U[5]
D1	41°42'35"	86°00'15"	10/13/77	A	19.3	10.0	2	BS	U
D2	41°42'35"	86°00'15"	10/03/77	R	176.0	5.0	5	PVC	U[5]
D3	41°42'35"	86°00'15"	10/03/77	R	90.0	10.0	5	PVC	U
E1	41°44'46"	86°00'25"	10/11/77	R	81.0	10.0	5	PVC	U
E2	41°44'46"	86°00'25"	11/03/77	A	17.4	10.0	2	BS	U
E3	41°44'46"	86°00'25"	10/11/77	R	176.0	5.0	5	PVC	U[5]

Table 1.--Description of wells in the Elkhart monitoring network--Continued

Well number	Latitude [1]	Longitude [1]	Date installed	Method of drilling [2]	Well depth (feet)	Screen length (feet)	Casing diameter (inches)	Casing material [3]	Aquifer type [4]
				Wells near the landfill--Continued					
F1	41°42'10"	85°59'56"	10/13/77	A	31.5	10.0	2	PVC	U
F2	41°42'10"	85°59'56"	10/12/77	R	155.0	5.0	5	PVC	C
F5	41°42'10"	85°59'56"	10/11/77	R	198.0	10.0	5	PVC	C
G1	41°42'35"	85°59'29"	10/17/77	R	43.0	5.0	5	PVC	U
G3	41°42'35"	85°59'29"	10/17/77	R	172.0	10.0	5	PVC	C
H2	41°42'10"	85°58'45"	10/20/77	R	43.0	5.0	5	PVC	U
H4	41°42'10"	85°58'45"	10/20/77	R	108.0	10.0	5	PVC	C
I1	41°41'48"	86°00'18"	10/13/77	R	168.0	5.0	5	PVC	C
I2	41°41'48"	86°00'18"	11/03/77	A	15.4	10.0	2	BS	U
I3	41°41'48"	86°00'18"	10/13/77	R	37.0	5.0	5	PVC	U
J1	41°41'55"	85°59'41"	10/12/77	R	40.0	5.0	5	PVC	U
J2	41°41'55"	85°59'41"	11/02/77	A	17.8	10.0	2	BS	U
J3	41°41'55"	85°59'41'	10/12/77	R	154.0	5.0	5	PVC	C
K1	41°41'25"	86°00'03	10/13/77	R	62.0	5.0	5	PVC	U
K2	41°41'25"	86°00'03'	11/02/77	A	14.6	10.0	2	BS	U
K3	41°41'25"	86°00'03"	10/13/77	R	185.0	5.0	5	PVC	C
L1	41°41'44"	86°01'05'	10/14/77	R	62.0	5.0	5	PVC	U
L2	41°41'44"	86°01'05'	10/14/77	R	185.0	5.0	5	PVC	C
L4	41°41'44"	86°01'05"	11/03/77	A	17.2	10.0	2	BS	U
M1	41°42'19'	86°00'25"	05/03/79	A	103.6	5.0	2	GALV	U [5]
M2	41°42'19	86°00'25"	05/02/79	A	25.2	5.0	2	PVC	U
N	41°42'14'	86°00'37"	04/30/79	A	30.0	5.0	2	PVC	U
O	41°42'23'	86°00'13"	05/01/79	A	30.0	5.0	2	PVC	U
P	41°42'14"	86°00'13"	05/03/79	A	25.0	5.0	2	PVC	U
Q	41°41'59"	86°00'22'	04/26/79	A	25.0	5.0	2	PVC	U
				Wells near the rivers					
R1	41°40'40"	86°02'03"	09/12/78	A	20.2	4.0	2	BS	U
R2	41°41'34"	85°58'08"	09/13/78	A	22.5	4.0	2	BS	U
R3	41°41'43'	85°57'53"	09/13/78	A	23.5	3.0	2	BS	U
R6	42°44'22"	85°59'16"	09/18/78	A	22.8	2.5	2	BS	U
R11	41°43'22"	85°59'17"	09/13/78	A	22.2	3.0	2	BS	U

[1] °, degrees; ', minutes; ", seconds.
[2] A, auger; R, rotary.
[3] BS, black steel; PVC, polyvinyl chloride; GALV, galvanized steel.
[4] U, unconfined aquifer; C, confined aquifer.
[5] Well is in area where confining layer is absent; however, because well is screened in the lower part of the aquifer, data from this well is included with data from wells in the confined aquifer on figures and in tables.

(6) Field alkalinity was analyzed by use of a pH meter and a method described by Fishman and Friedman (1989, p. 55-56). A 100-mL unfiltered sample was titrated with a standard solution of sulfuric acid to a fixed end point of 4.5 pH units.

(7) The bromide samples were sent to USGS laboratories for analysis. Three different methods for determining the concentration of dissolved bromide were used by the laboratories during the study period. Prior to 1985, bromide concentrations were determined by use of colorimetric, catalytic oxidation (Skougstad and others, 1979, p. 329-330). In 1985, ion-exchange chromatography (Fishman and Friedman, 1989, p. 115-117) was used. In 1986 and afterwards, bromide concentrations were determined by means of automated-segmented flow fluorescein colorimetry (Fishman and Friedman, 1989, p. 121-123).

GROUND-WATER LEVELS AND FLOW

Ground-water levels were measured twice a year, in the spring and fall, by employees of the Elkhart Water Works. The biannual water-level measurements provided an estimate of the seasonal fluctuations of the ground-water levels. Wells from which water samples were obtained for water-quality analysis had an additional water-level measurement made each year at the time of sampling. The number of water-level measurements per well ranged from 10 to 27 for 1980-89. Ground-water altitudes were determined from the measurements and are listed in table 2 at the end of the report.

During 1980-89, measured ground-water levels ranged from about 6 ft above ground level in well 17D, a flowing well near the river, to about 29 ft below ground level in well G3. The average depth to water for all wells throughout the study area was 10 ft.

Ground-water levels fluctuate in response to the volume and distribution of recharge and discharge in the aquifer. The aquifers in the study area are recharged by infiltration of precipitation. Discharge occurs naturally by evapotranspiration and seepage to streams and artificially by pumping. Ground-water levels fluctuate seasonally and generally are highest in April and May and lowest in September and October. Seasonal fluctuations are shown by the hydrograph of Elkhart 5 (fig. 6), an observation well screened in the unconfined aquifer and equipped with a water-stage recorder. For 1980-89, the average seasonal fluctuation in this well was 2.8 ft. Similar fluctuations were determined from the spring and fall measurements made in monitoring wells throughout the study area. For the entire period of study, water-level fluctuations ranged from 1.8 ft at well R1 to 16.9 ft at well K3. The large fluctuation at well K3 probably is caused by nearby ground-water pumping. The average fluctuation for all wells during the entire study period was 4.8 ft.

Ground-water levels were plotted on maps and contoured to determine the direction of ground-water flow in the study area. Maps were drawn for each time that measurements were made, and the maps were compared to determine if changes in flow directions had occurred during the period of study. No substantial differences were found between the maps; however, minor differences were noted. The differences are caused by fluctuations of the water levels that result in a shifting of the contour lines along the direction of flow. Contour lines were shifted downgradient for periods of high water levels and upgradient for periods of low water levels. Because there was no single time when all the water levels were highest or lowest, water levels measured during April 1986 were selected as representative of conditions in the study area.

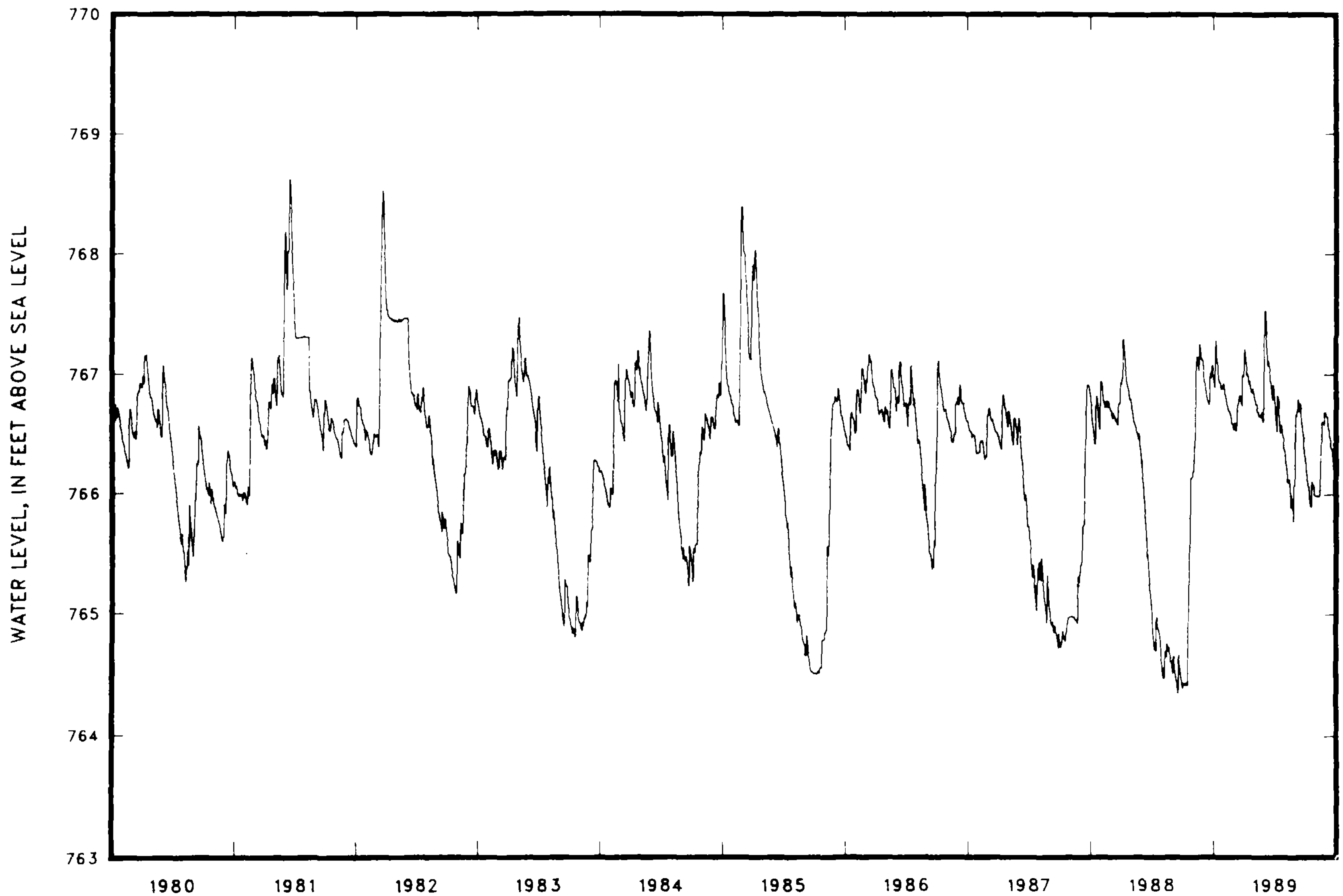


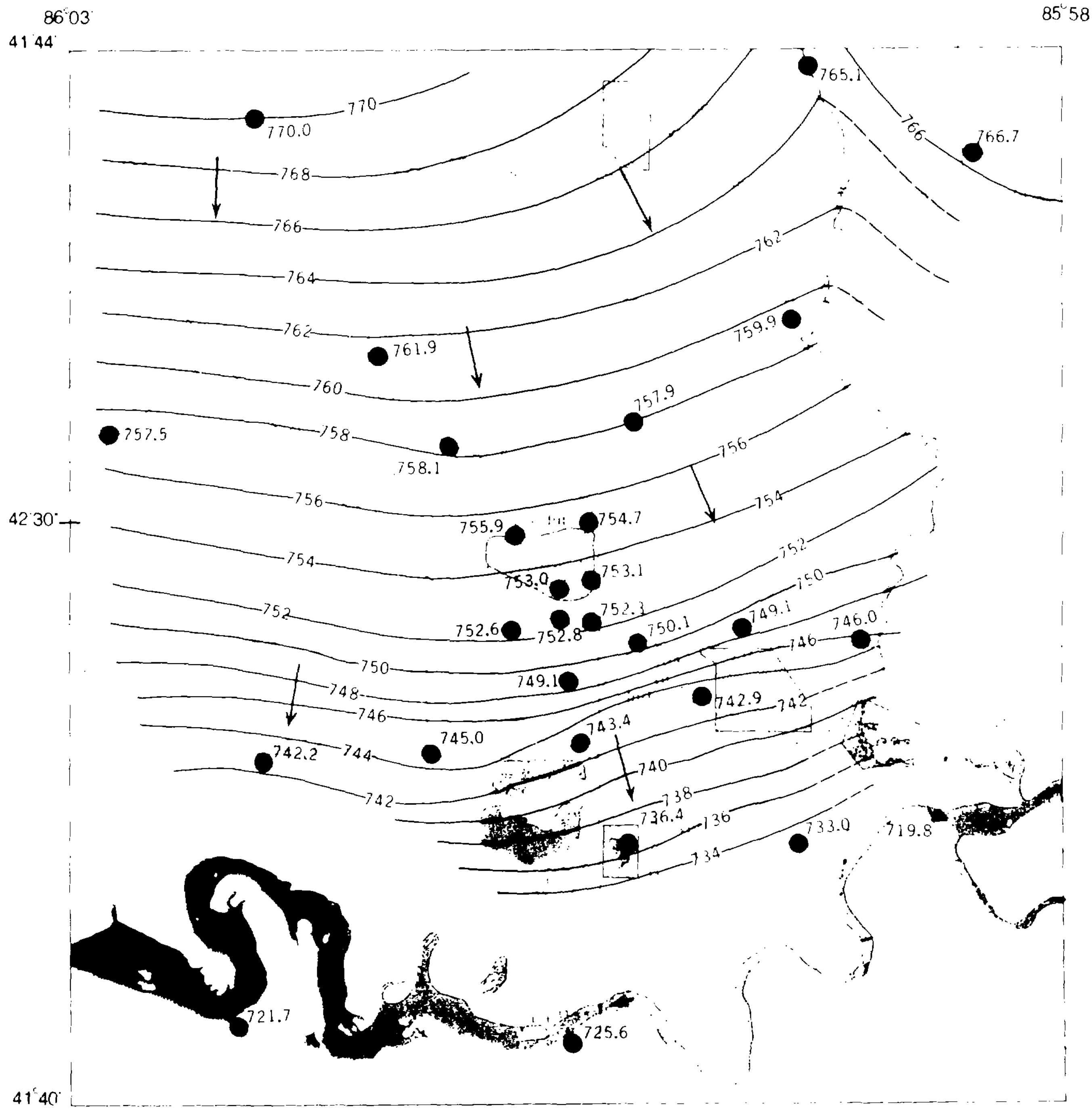
Figure 6.–Water levels in recording well, Elkhart 5, 1980-89.

Water levels in the unconfined aquifer in the area near the landfill are shown on figure 7. The direction of ground-water flow is perpendicular to the contour lines and, in the mapped area, is generally toward the south-southeast and the St. Joseph River. River stage was estimated by use of the average gage height for April 14-19, 1986, determined from records at a USGS streamflow-gaging station located on the St. Joseph River approximately 200 ft downstream from the mouth of the Elkhart River. Ground-water levels near the river are higher than the stage of the river, indicating that ground water discharges to the river.

The water-level map for the confined aquifer (fig. 8) shows the effect of pumping in an industrial area and at the Elkhart Water Works' Bower Street well field. The contour lines bend around the pumping centers and are closely spaced, indicating that water levels are being lowered by the pumping. The area in which water levels are lowered by pumping is known as a cone of depression. Cones of depression due to industrial pumping were apparent on water-level maps for the confined aquifer for each time that measurements were made. Cones of depression due to pumping from the Bower Street well field were not always apparent, probably because this well field is used primarily to supplement pumping from the Main Street well field; therefore, it is used only intermittently during periods of increased water demand.

The distance between contour lines indicates the slope of the water surface or horizontal hydraulic gradient. In the area near the landfill, the hydraulic gradient increases to the south and is steepest near the river and areas of pumping. North of the landfill, horizontal hydraulic gradients in both aquifers average about 1.5×10^{-3} ft/ft, or 7.9 ft/mi. South of the landfill, the horizontal hydraulic gradients average about 2.7×10^{-3} ft/ft (14.3 ft/mi). Water levels in wells 17S and R1 (fig. 5), which are less than 200 ft from the river and screened in the unconfined aquifer, are 2 to 6 ft higher than the river stage, indicating that gradients near the river are steep. Horizontal hydraulic gradients in the confined aquifer are steepest near areas of pumping. For example, the gradient measured between wells I1 and K3 during April 1986 was 9.0×10^{-3} ft/ft (47.5 ft/mi).

Vertical hydraulic gradients were determined at sites where there were two or more wells screened at different depths. In the study area, there are 20 sites that have at least one well screened in the unconfined aquifer and one well screened in the confined aquifer. The average difference between water levels was less than 2 ft at 13 of the 20 sites; at 8 of these sites, water levels were higher in the confined aquifer than in the unconfined aquifer. Average water-level differences at the remaining seven sites ranged from 2.3 to



Base from U.S. Geological Survey Elkhart 1:24,000, 1961, revised 1981, and Osceola 1:24,000, 1969, revised 1980

EXPLANATION

—766— — WATER-LEVEL CONTOUR--Shows altitude of water level. Dashed where approximately located. Contour interval 2 feet. Datum is sea level

0 1 2 MILES

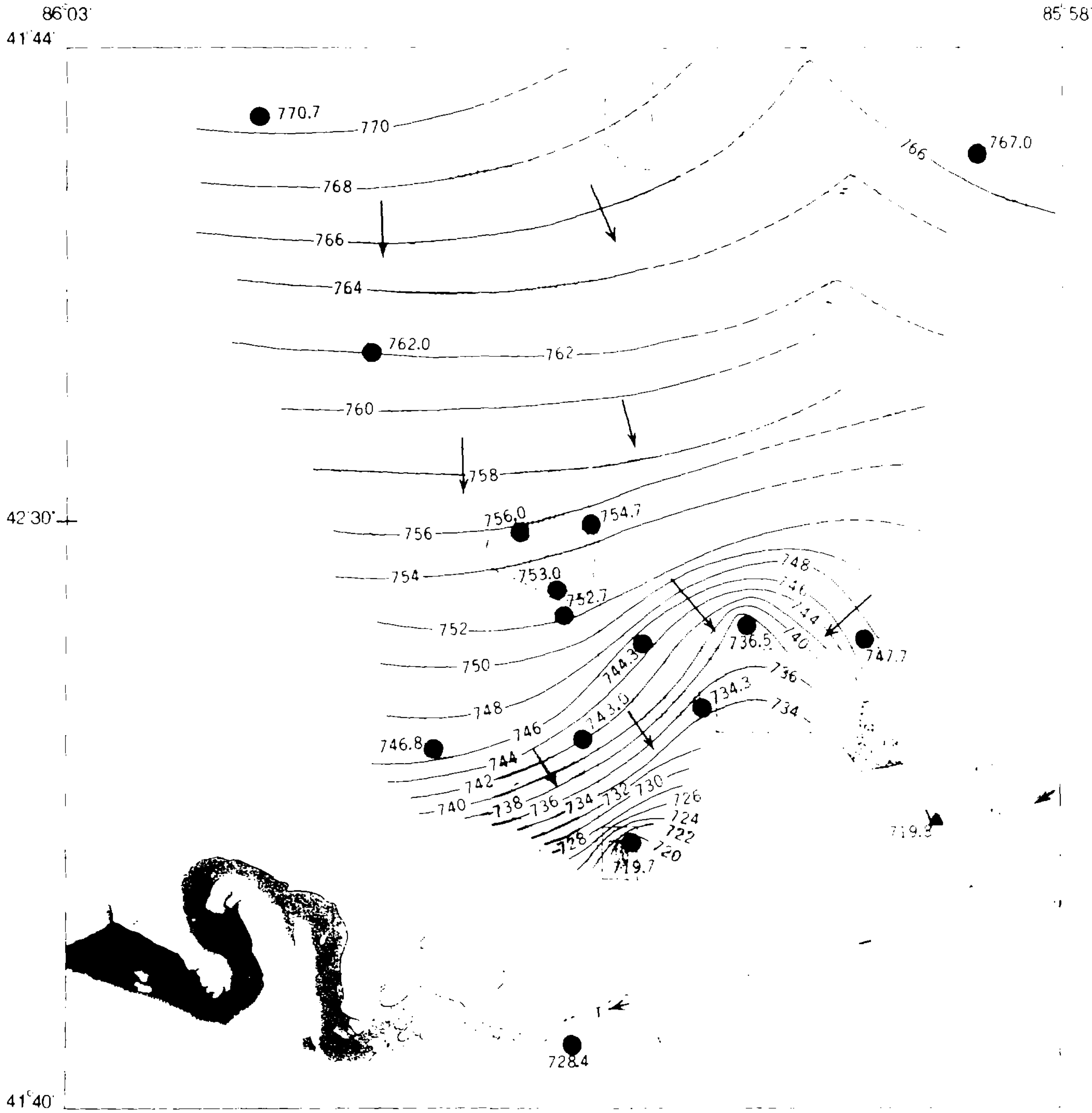
0 1 2 KILOMETERS

↘ DIRECTION OF FLOW

745.0 ● MONITORING WELL-- Number is water-level altitude in feet above sea level

▲ STREAMFLOW-GAGING STATION--Number is river stage in feet above sea level

Figure 7.--Water levels and direction of flow in the unconfined aquifer, April 1986.



Base from U.S. Geological Survey Elkhart 1:24,000, 1961, revised 1981, and Osceola 1:24,000, 1969, revised 1980

EXPLANATION

—766— — WATER-LEVEL CONTOUR--Shows altitude of water level. Dashed where approximately located. Contour interval 2 feet. Datum is sea level

0 1 2 MILES

0 1 2 KILOMETERS

DIRECTION OF FLOW

745.0 ● MONITORING WELL-- Number is water-level altitude in feet above sea level

▲ STREAMFLOW-GAGING STATION--Number is river stage in feet above sea level

Figure 8.--Water levels and direction of flow in the confined aquifer, April 1986.

13.1 ft. These seven sites were located either near streams or near areas of pumping. Near streams, water levels were higher in the confined aquifer than in the unconfined aquifer, indicating upward flow of ground water toward the stream. Near the areas of pumping, water levels were lower in the confined aquifer than in the unconfined aquifer, indicating downward flow toward the confined aquifer.

Vertical hydraulic gradients were determined by dividing the difference between water levels by the distance between the screened interval of each pair of wells. Vertical hydraulic gradients between the aquifers ranged from 9.5×10^{-5} to 7.7×10^{-2} ft/ft and had an average value of 5.5×10^{-3} ft/ft. The largest vertical gradients are probably across the confining clay and silt layer between the two aquifers. Vertical gradients generally were not measured within each aquifer except in wells at sites C and F, where vertical gradients were measured in the confined aquifer. At site C, upward and downward gradients were measured in the confined aquifer. At site F, the gradient in the confined aquifer was downward and is probably caused by pumping.

GROUND-WATER QUALITY

Water-quality samples were collected at least once a year (except in 1981) from most of the wells in the landfill area. The number of samples collected from each well during 1980-89 ranged from 6 to 10. The samples were analyzed to determine concentrations of dissolved bromide in the ground water. Onsite measurements of specific conductance, ph, water temperature, dissolved oxygen, and alkalinity were made at the time of sampling. Results of the bromide analyses and onsite measurements are listed in table 3 at the end of the report.

During 1980-89, all of the water samples collected had a median specific conductance of 516 µS/cm, a median pH of 7.6, a median alkalinity of 216 mg/L (milligrams per liter), and a median dissolved-bromide concentration of 0.08 mg/L. In order to describe the ground-water quality in the study area adequately, the monitoring wells were grouped according to their depth and position in relation to the ground-water-flow system and the landfill. Wells were assigned to one of three groups: (1) shallow wells that are upgradient from the landfill, (2) shallow wells that are in or downgradient from the landfill, and (3) deep wells. For this purpose, shallow wells were defined as those being less than 100 ft deep; deep wells were those more than 100 ft deep. Generally, shallow wells were screened in the unconfined aquifer, and deep wells were screened in the confined aquifer.

Shallow wells that are upgradient from the landfill are 29S, 31, 41S, D1, D3, and G1. Shallow wells that are in or downgradient from the landfill are 51, E1, E2, F1, I2, I3, J1, J2, K1, K2, M2, N, O, P, and Q. Deep wells are 29D, 41D, D2, G3, E3, F2, F5, I1, J3, M1, and K3. Mean, median, minimum, and maximum values were determined for specific conductance, ph, dissolved oxygen, alkalinity, and dissolved bromide for water samples from each well and for each group of wells and are listed in table 4. Median values were selected to best describe the data because they are not as affected, as are mean values, by extreme values that are common in water-quality data. For example, water collected in 1989 from well D3 had an anomalously large dissolved-bromide concentration of 27 mg/L. The mean dissolved-bromide concentration of all other water samples from this well during the study period was 0.12 mg/L. Including the 27 mg/L value, the mean dissolved-bromide concentration for water from this well was 3.1 mg/L, and the mean dissolved-bromide concentration for water from all shallow wells upgradient from the landfill is 0.58 mg/L. The median values of 0.08 mg/L for well D3 and 0.04 mg/L for all shallow wells upgradient from the landfill are more typical of the dissolved-bromide concentrations in water from these wells and are more descriptive of the ambient concentrations in ground water in the study area.

Comparison of the shallow wells upgradient from the landfill and the deep wells indicates that there is not much difference between the median values of specific conductance, pH, and dissolved-bromide concentrations for these two groups. There was generally less dissolved oxygen in water from the deep wells than in water from the shallow wells upgradient from the landfill. Imbrigiotta and Martin (1981, p. 102) found oxidizing conditions in the shallow wells and reducing conditions in the deep wells during their study. Water from the deep wells had larger values of alkalinity than water from the shallow wells upgradient from the landfill, probably because the deep water has been in contact with the calcareous glacial sediments in the confined aquifer for a longer time than water in the shallow unconfined aquifer.

It should be noted that water from two deep wells, E3 and M1, had larger specific-conductance values and dissolved-bromide concentrations compared to water from other deep wells. Water from well E3 had relatively large concentrations of dissolved bromide throughout the period of study. Concentrations of dissolved bromide in water from well M1 generally decreased during the study. These wells are nearer to the landfill than any of the other deep wells, and because the confining layer is absent in this area, these wells are affected by the plume of leachate caused by dissolution of soluble materials buried in the landfill. Therefore, wells E3 and M1 are not typical of the other deep wells in the study area.

Comparison of the shallow wells downgradient from the landfill and the other two groups of wells indicates a difference for most of the water-quality parameters that were measured. The median values of specific conductance and alkalinity and dissolved-bromide concentrations were larger in water from the shallow wells downgradient from the landfill than in water from shallow wells upgradient from the

Table 4.--Means, medians, minimums, and maximums of specific conductance and pH values and dissolved-oxygen, alkalinity, and dissolved-bromide concentrations in water from shallow wells upgradient from the landfill, deep wells, and shallow wells downgradient from the landfill, 1980-89

[All values in milligrams per liter except specific conductance, which is in microsiemens per liter at 25 degrees Celsius, and pH, which is in standard units. <, less than]

Well number	Number of samples	Specific conductance Mean	Median	Minimum	Maximum	pH Mean	Median	Minimum	Maximum	Dissolved oxygen Mean	Median	Minimum	Maximum	Alkalinity Mean	Median	Minimum	Maximum	Dissolved bromide Mean	Median	Minimum	Maximum
											Shallow wells upgradient from the landfill										
29S	9	497	501	463	522	7.7	7.7	7.5	8.0	0.8	0.8	<0.1	1.9	130	128	120	144	0.05	0.04	0.03	0.10
31	9	381	360	348	472	7.8	7.8	7.7	8.0	4.3	4.2	2.1	6.0	137	135	125	154	.04	.03	.02	.10
41S	9	334	324	290	386	8.2	8.2	7.9	8.4	4.8	4.6	4.0	6.1	97	100	72	116	.12	.04	.01	.70
D1	9	406	396	335	500	7.8	7.9	7.6	8.0	5.9	6.3	3.6	7.4	125	122	100	166	.05	.03	.01	.20
D3	9	484	479	422	540	7.8	7.8	7.6	8.0	1.2	1.2	< .1	2.4	163	160	145	180	3.1	.08	.03	27.0
G1	8	474	476	410	532	7.7	7.8	7.5	7.9	.7	.9	< .1	1.6	184	180	173	194	.04	.04	.01	.10
											All shallow wells upgradient from the landfill										
	53	429	445	290	540	7.8	7.8	7.5	8.4	3.0	2.4	<0.1	7.4	139	135	72	194	0.58	0.04	0.01	27.0
											Deep wells										
29D	9	503	502	489	517	7.5	7.5	7.4	7.8	0.6	0.4	<0.1	1.8	260	260	251	270	0.13	0.03	0.01	0.86
41D	9	521	516	500	550	7.6	7.5	7.4	7.7	.5	.6	< .1	1.0	269	275	202	295	.02	.03	< .01	.04
D2	9	417	417	392	455	7.7	7.7	7.6	7.9	1.3	.7	< .1	4.6	192	190	173	230	.05	.03	.03	.20
E3	9	947	980	767	1,130	7.6	7.5	7.0	8.1	.5	.4	< .1	1.7	413	405	362	516	2.7	2.7	1.3	3.3
F2	9	385	387	364	410	7.7	7.8	7.3	7.9	.7	.4	< .1	2.2	193	189	184	216	.02	.01	< .01	.10
F5	9	462	464	392	558	7.7	7.8	7.3	8.0	.8	.8	< .1	1.8	217	220	192	234	.07	.07	.04	.11
G3	8	506	518	446	545	7.8	7.8	7.7	8.0	2.1	1.1	< .1	5.5	221	220	209	230	.05	.04	.03	.10
I1	9	411	413	391	443	7.9	7.9	7.5	8.1	1.2	.6	< .1	6.1	220	215	195	252	.03	.02	< .01	.10
J3	9	454	455	399	511	7.7	7.6	7.5	8.0	.8	.7	< .1	2.4	288	232	209	240	.04	.04	< .01	.07
K3	10a	436	431	383	502	7.7	7.8	7.0	8.1	.9	.6	< .1	4.0	198	192	187	216	.09	.08	.04	.20
M1	9	954	1,000	810	1,070	7.4	7.4	6.8	7.9	1.0	.7	< .1	3.7	340	337	290	370	1.4	.83	.19	4.6
											All deep wells										
	99a	544	474	364	1,130	7.7	7.7	6.8	8.1	0.9	0.6	<0.1	6.1	250	230	173	516	0.42	0.04	<0.01	4.6

Table 4.--Means, medians, minimums, and maximums of specific conductance and pH values and dissolved-oxygen, alkalinity, and dissolved-bromide concentrations in water from shallow wells upgradient from the landfill, deep wells, and shallow wells downgradient from the landfill, 1980-89--Continued

Well number	Number of samples	Specific conductance Mean	Specific conductance Median	Specific conductance Minimum	Specific conductance Maximum	pH Mean	pH Median	pH Minimum	pH Maximum	Dissolved oxygen Mean	Dissolved oxygen Median	Dissolved oxygen Minimum	Dissolved oxygen Maximum	Alkalinity Mean	Alkalinity Median	Alkalinity Minimum	Alkalinity Maximum	Dissolved bromide Mean	Dissolved bromide Median	Dissolved bromide Minimum	Dissolved bromide Maximum
									Shallow wells downgradient from the landfill												
51	6	597	623	523	668	7.1	7.1	7.0	7.3	1.3	0.9	0.1	3.4	196	219	130	230	0.06	0.07	0.03	0.09
E1	9	1,017	1,020	952	1,070	7.4	7.3	6.9	7.8	.6	.5	< .1	1.8	383	384	347	420	1.7	1.3	.26	4.2
E2	9	577	310	248	1,700	7.2	7.1	6.7	7.4	.9	1.0	< .1	1.7	191	125	87	389	.60	.07	< .01	3.2
F1	8	696	685	497	826	7.6	7.6	7.3	8.0	.3	.2	< .1	1.1	218	225	172	257	.14	.11	.01	.39
I2	9	497	526	290	653	7.4	7.4	7.1	7.6	3.9	5.7	< .1	6.6	169	174	150	181	.10	.08	.04	.30
I3	9	1,030	1,050	769	1,350	7.4	7.3	7.2	7.6	.6	.6	< .1	1.7	489	460	396	624	2.6	2.6	2.1	3.2
J1	9	716	734	480	966	7.4	7.4	7.3	7.7	.4	.6	< .1	.7	258	228	202	330	.56	.40	.06	1.7
J2	8	740	794	309	996	7.2	7.0	6.7	7.8	4.2	4.0	.3	7.9	288	310	150	420	.10	.05	.03	.40
K1	10a	476	447	393	606	7.6	7.7	6.9	8.0	1.0	.7	< .1	3.5	196	201	150	225	.61	.78	< .01	.90
K2	9	718	775	394	990	7.1	7.1	6.5	7.5	1.1	.9	< .1	4.0	256	263	210	286	.36	.27	.20	.71
M2	9	1,104	1,070	380	2,200	6.9	6.9	6.4	7.1	.7	.3	< .1	2.2	578	542	380	1,000	2.5	2.3	2.0	3.8
N	9	1,053	1,050	784	1,390	7.3	7.3	6.8	7.6	.6	.3	< .1	2.6	374	350	170	574	1.4	1.7	.10	2.7
O	9	583	600	478	675	7.7	7.7	7.4	7.9	1.1	.6	.2	5.0	134	128	120	180	.06	.05	.04	.10
P	9	1,316	1,420	308	1,660	7.2	7.1	6.7	8.2	1.3	.9	< .1	4.7	630	670	100	893	1.2	.86	.29	3.0
Q	9	1,249	1,230	1,010	1,400	7.2	7.2	7.0	7.4	.7	.6	< .1	2.2	578	580	428	682	2.1	2.3	.30	4.7
									All shallow wells downgradient from the landfill												
	131a	829	775	248	2,200	7.3	7.3	6.4	8.2	1.2	0.6	<0.1	7.9	334	274	87	1,000	0.97	0.40	<0.01	4.7
									All shallow wells less than 0.5 mile downgradient from the landfill												
	72	981	1,025	248	2,200	7.2	7.3	6.4	8.2	1.2	0.6	<0.1	6.6	424	415	87	1,000	1.5	1.6	<0.01	4.7
									All shallow wells more than 0.5 mile downgradient from the landfill												
	59a	644	623	309	999	7.4	7.5	6.5	8.0	1.3	0.6	<0.1	7.9	221	212	120	420	0.29	0.12	<0.01	1.7

(a) Dissolved oxygen and alkalinity have one less sample.

landfill or deep wells. Water from the shallow wells downgradient from the landfill generally had smaller pH values than water from the two other groups of wells. The median dissolved-oxygen concentration in water from the shallow wells downgradient from the landfill was smaller than in water from shallow wells upgradient from the landfill but was about the same as in water from the deep wells.

The quality of water from shallow wells downgradient from the landfill indicates that soluble materials buried in the landfill are being dissolved and transported by the ground water. The specific conductance of water is proportional to the ionic concentration such that an increase in specific conductance indicates an increase in dissolved-solids concentration (Hem, 1985, p. 66). Landfill leachate typically contains large concentrations of dissolved solids and can have small values of pH (Lu and others, 1985, p. 108). Values of ph were only slightly smaller in shallow wells downgradient from the landfill compared to shallow wells upgradient from the landfill and deep wells. Alkalinity concentrations were largest in shallow wells downgradient from the landfill, indicating that the sediments in the unconfined aquifer probably buffer the leachate and preclude extremely small pH values.

The effect of the landfill on water quality is defined further by dividing the shallow wells downgradient from the landfill into wells less than 0.5 mi directly downgradient from the landfill and wells more than 0.5 mi downgradient or not directly downgradient from the landfill. Shallow wells less than 0.5 mi downgradient from the landfill are E1, E2, I2, I3, M2, N, P, and Q. Shallow wells more than 0.5 mi downgradient or not directly downgradient are 51, F1, J1, J2, K1, K2, and O. In this comparison, water from the wells nearest to the landfill had larger specific-conductance values and dissolved-bromide concentrations than water from wells farther from the landfill. The median specific conductance was 1,025 μS/cm, and the median dissolved-bromide concentration was 1.6 mg/L for water from wells less than 0.5 mi directly downgradient from the landfill compared to a median specific conductance of 623 μS/cm, and a median dissolved-bromide concentration of 0.12 mg/L for water from wells more than 0.5 mi downgradient from the landfill.

Distribution of Dissolved-Bromide Concentrations

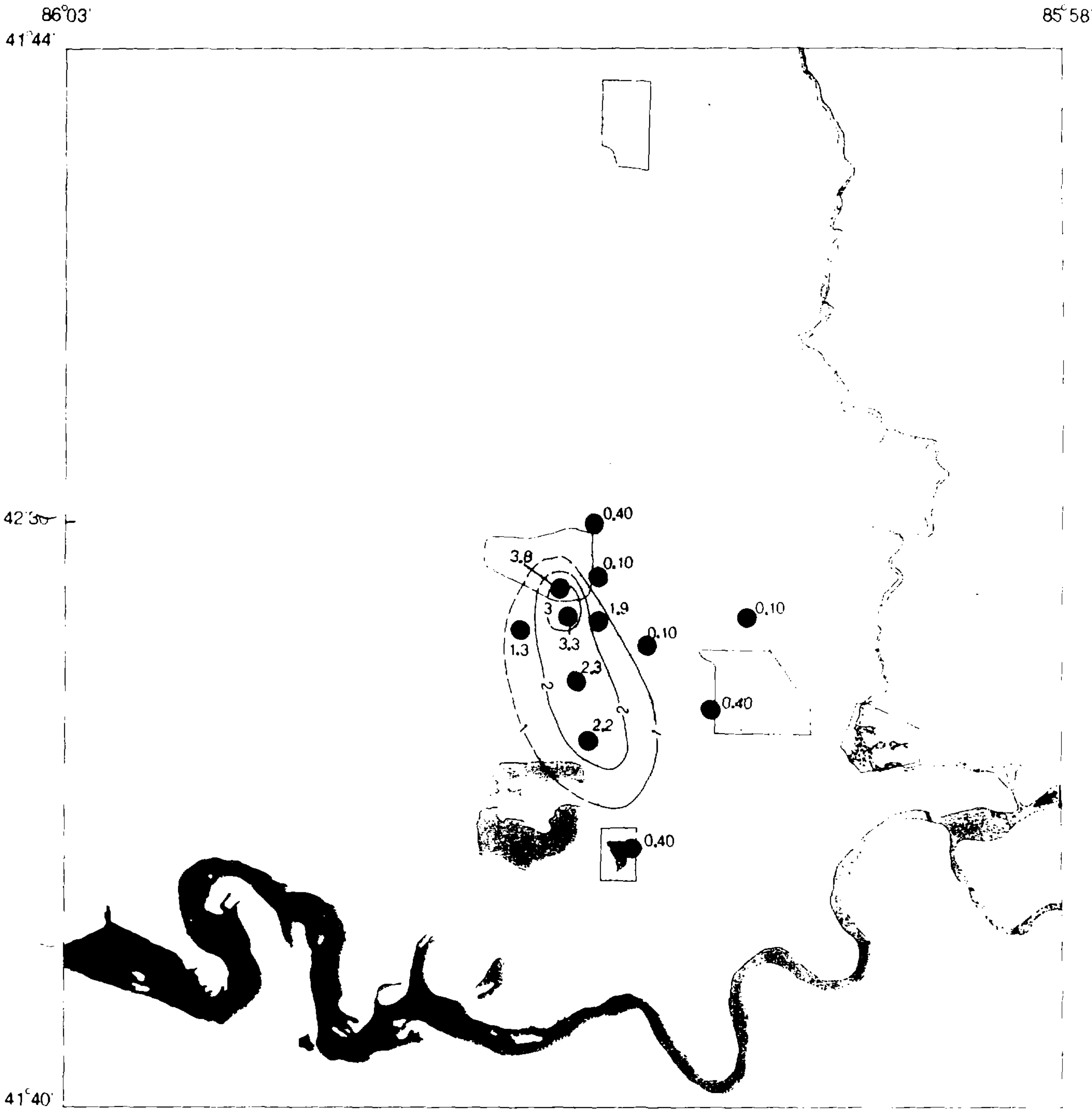
Imbrigiotta and Martin (1981, p. 128) determined that bromide was the best indicator of landfill leachate in the study area. In addition to being present in relatively large concentrations in the landfill leachate compared to concentrations in the ambient ground water, bromide is conservative; that is, it is not affected greatly by chemical reactions or microbial activity as it moves along the ground-water flow path. Therefore, dissolved-bromide concentrations in the ground water in and downgradient from the landfill probably indicate the maximum extent of leachate migration from the landfill.

The dissolved-bromide-concentration values were plotted on maps and hydrogeologic sections and contoured to determine the areal and vertical distribution of bromide in the aquifers. At locations where more than one well was screened in an aquifer, the concentration plotted on the maps represents the maximum concentration detected in the aquifer at that location. Maps and sections from different sampling periods were compared to determine how the distribution of dissolved bromide changed during the study period. Dissolved-bromide concentrations for three sampling periods (1980, 1982, and 1988) were selected to describe changes in bromide distribution during 1980-89.

Maximum dissolved-bromide concentrations in water samples collected during November and December 1980 are shown on figure 9. The areal distribution of bromide concentrations follows the general direction of ground-water flow and indicates the presence of a leachate plume in and downgradient from the landfill. The largest concentrations of dissolved bromide were detected in water from well M2 (3.8 mg/L) in the landfill and in water from well E3 (3.3 mg/L), the downgradient well nearest to the landfill. The dissolved-bromide plume extended south of the landfill to a location between well sites I and K. Water from wells upgradient and downgradient from the landfill not affected by landfill leachate had dissolved-bromide concentrations that were generally less than 0.5 mg/L.

Dissolved-bromide concentrations in water samples collected during July and August 1982 (fig. 10) were generally the largest detected during the study period. The largest dissolved-bromide concentration was 4.7 mg/L, detected in water from well Q. The dissolved-bromide plume extends south to well K1 where a dissolved-bromide concentration of 0.73 mg/L was detected in water from the 62-ft deep well. In addition, a dissolved-bromide concentration of 1.7 mg/L was detected in water from well J1, a 40-ft deep well located near the area of industrial pumping. Dissolved-bromide concentrations in water from shallow wells at J1, J2, K1, and K2 ranged from not detected (less than 0.01 mg/L) to 1.7 mg/L during the study. Maximum concentrations of 1.7 mg/L in water from well J1 and 0.9 mg/L in water from well K1 were detected. These concentrations indicate that water from the landfill has reached these wells during the study period. Although wells J1 and J2 are not directly downgradient from the landfill, industrial pumping near these wells could draw the plume toward the area.

Dissolved-bromide concentrations in water samples collected from the unconfined aquifer in August 1988 (fig. 11) were generally the smallest detected during the study. The largest dissolved-bromide concentration was 3.1 mg/L, detected in water



Base from U.S. Geological Survey Elkhart 1:24,000, 1961, revised 1981, and Osceola 1:24,000, 1969, revised 1980

EXPLANATION

——2—— LINE OF EQUAL CONCENTRATION OF DISSOLVED BROMIDE--Dashed where approximately located. Interval 1 milligram per liter

● 2.3 MONITORING WELL--Number is dissolved-bromide concentration, in milligrams per liter

0 1 2 MILES

0 1 2 KILOMETERS

Figure 9.-- Areal distribution of maximum concentrations of dissolved bromide in ground water near the landfill, November and December 1980.

Base from U.S. Geological Survey Elkhart 1:24,000, 1961, revised 1981, and Osceola 1:24,000, 1969, revised 1980

EXPLANATION

—— 2 — — LINE OF EQUAL CONCENTRATION OF DISSOLVED BROMIDE--Dashed where approximately located. Interval 1 milligram per liter

● 2.3 MONITORING WELL--Number is dissolved-bromide concentration, in milligrams per liter

0 1 2 MILES

0 1 2 KILOMETERS

Figure 10.--Areal distribution of maximum concentrations of dissolved bromide in ground water near the landfill, July and August 1982.

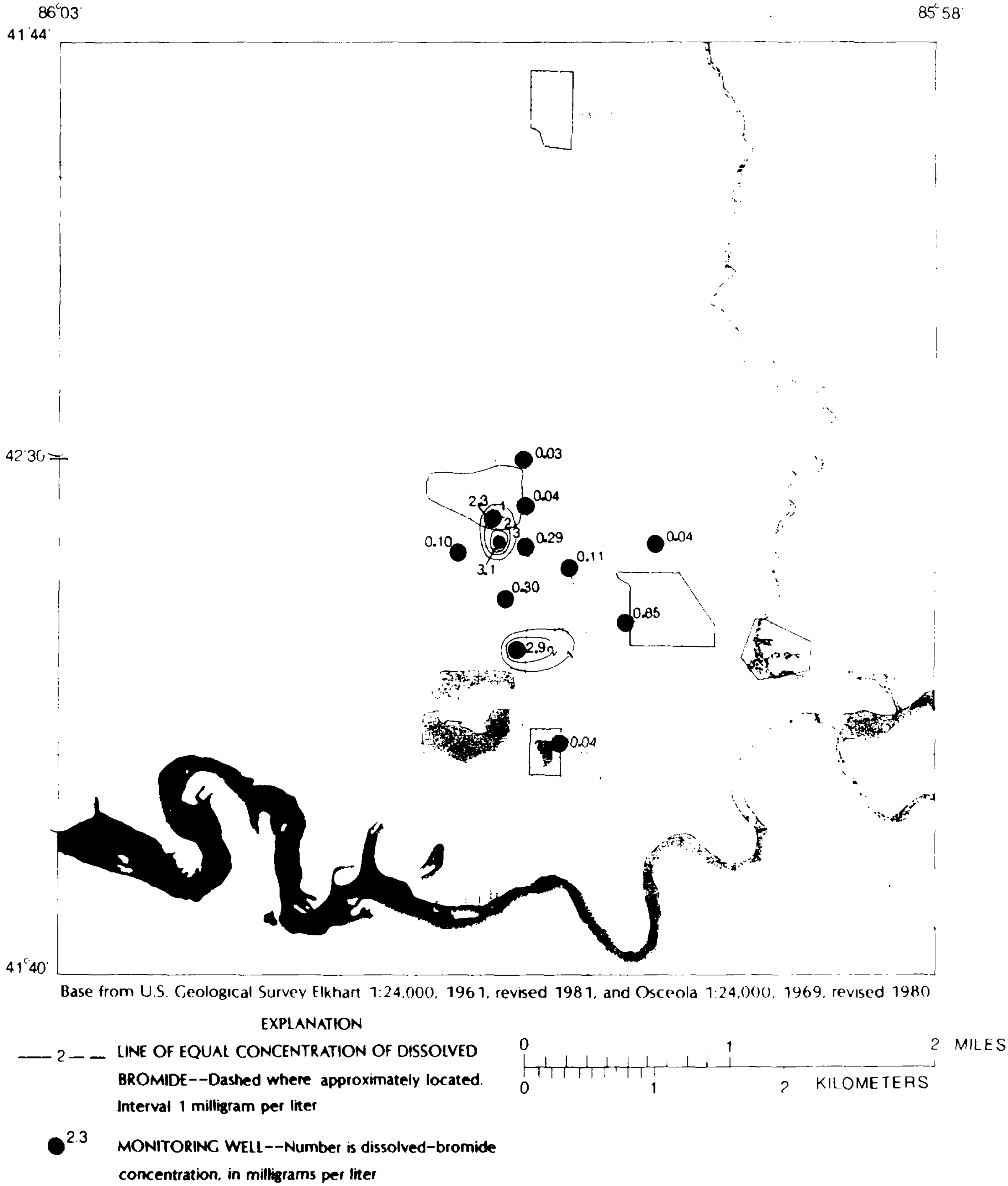


Figure 11.--Areal distribution of maximum concentrations of dissolved bromide in ground water near the landfill, August 1988.

from well E3. Smaller dissolved-bromide concentrations in water from well Q compared to the concentrations in water from wells at sites E and I indicate a separation of the dissolved-bromide plume south of the landfill. Similar plume separations were noted on dissolved-bromide-concentration maps drawn for sampling periods in 1983, 1984, 1986, 1987, and 1989. Dissolved-bromide concentrations in water from wells K1 and K2 were similar to those detected in water from these wells in 1980. Dissolved-bromide concentrations in water from wells J1 and J2 were larger than the dissolved-bromide concentrations detected in water from these wells in 1980 but smaller than those detected in 1982.

Dissolved-bromide concentrations were distributed vertically as well as horizontally in the aquifers. The vertical distribution of dissolved bromide for sampling periods in 1980, 1982, and 1988 along the hydrogeologic section A-A' (fig. 5) from site M to site K, are shown on figures 12, 13, and 14. The relatively large concentrations of dissolved bromide that were detected in water from deep wells E3, for all sampling periods, and M1, for the 1980 and 1982 sampling periods, indicate that water from the shallow portion of the aquifer has moved vertically downward beneath the landfill. From 1982 to 1988, dissolved-bromide concentrations generally decreased in water from well E1 (81 ft deep) and well E2 (17 ft deep), but remained about the same in water from well E3 (176 ft deep). Water containing dissolved bromide has also moved vertically downward in the unconfined aquifer downgradient from the landfill. Water from well I3 in the unconfined aquifer had dissolved-bromide concentrations larger than those in water from the shallower well I2. The downward movement of the leachate plume associated with the relatively large dissolved-bromide concentrations could be caused by downward hydraulic gradients between wells I2 and I3, by differences in density between the plume and the ambient ground water, or by dilution through recharge from above.

The variability of dissolved-bromide concentrations in water from individual wells depends on the position of the well in relation to the landfill. During the study, dissolved-bromide concentrations in individual wells exhibited one of three general patterns: (1) concentrations remained the same, (2) concentrations fluctuated, or (3) concentrations decreased. These patterns are illustrated by a graph of dissolved-bromide concentrations over time for wells D1, E2, and Q (fig. 15).

Water from shallow wells upgradient from the landfill (such as D1) and deep wells screened in the confined aquifer had dissolved-bromide concentrations that were generally similar throughout the study period (fig. 15). Dissolved-bromide concentrations in water from these wells were generally the smallest detected and represented natural or ambient concentrations in the ground water. The similar concentrations throughout the study period indicated that ambient concentrations were relatively stable, and the small concentrations indicated that these wells were not affected by the landfill.

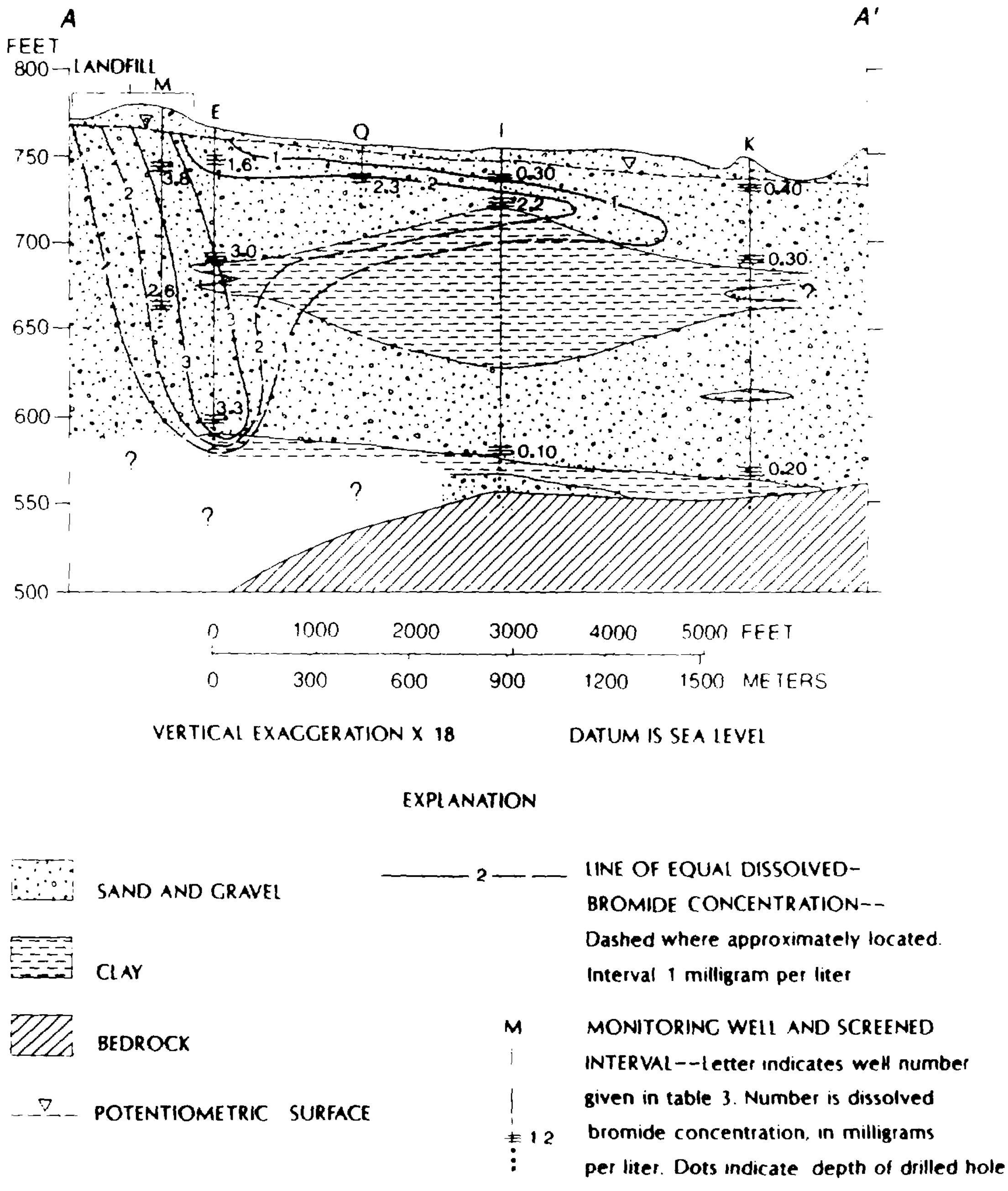
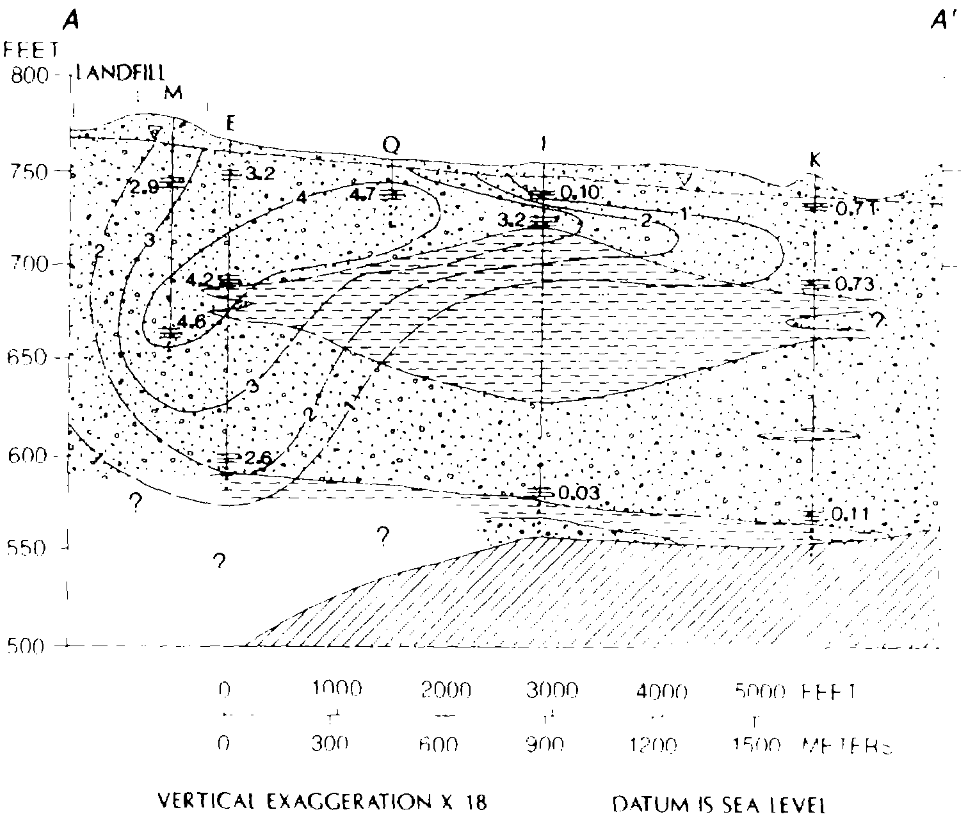


Figure 12.--Lithology and vertical distribution of concentrations of dissolved bromide along hydrogeologic section A-A', November and December 1980. Trace of section shown on figure 5.



EXPLANATION

SAND AND GRAVEL

CLAY

BEDROCK

POTENTIOMETRIC SURFACE

2 — LINE OF EQUAL DISSOLVED-BROMIDE CONCENTRATION--Dashed where approximately located. Interval 1 milligram per liter

M — MONITORING WELL AND SCREENED INTERVAL--Letter indicates well number given in table 3. Number is dissolved bromide concentration, in milligrams per liter. Dots indicate depth of drilled hole

Figure 13.–Lithology and vertical distribution of concentrations of dissolved bromide along hydrogeologic section A-A', July and August 1982. Trace of section shown on figure 5.

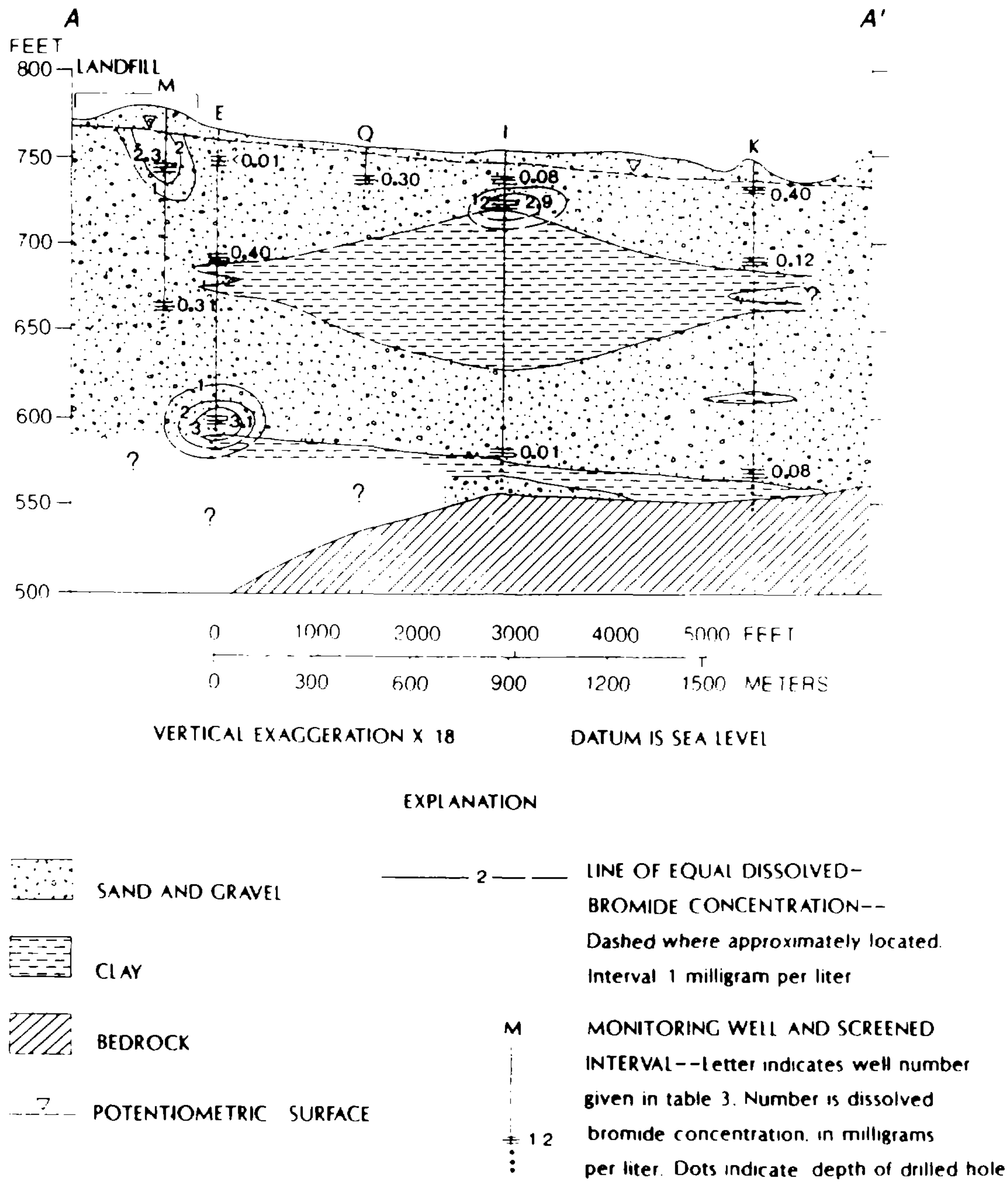


Figure 14.--Lithology and vertical distribution of concentrations of dissolved bromide along hydrogeologic section A-A', August 1988. Trace of section shown on figure 5.

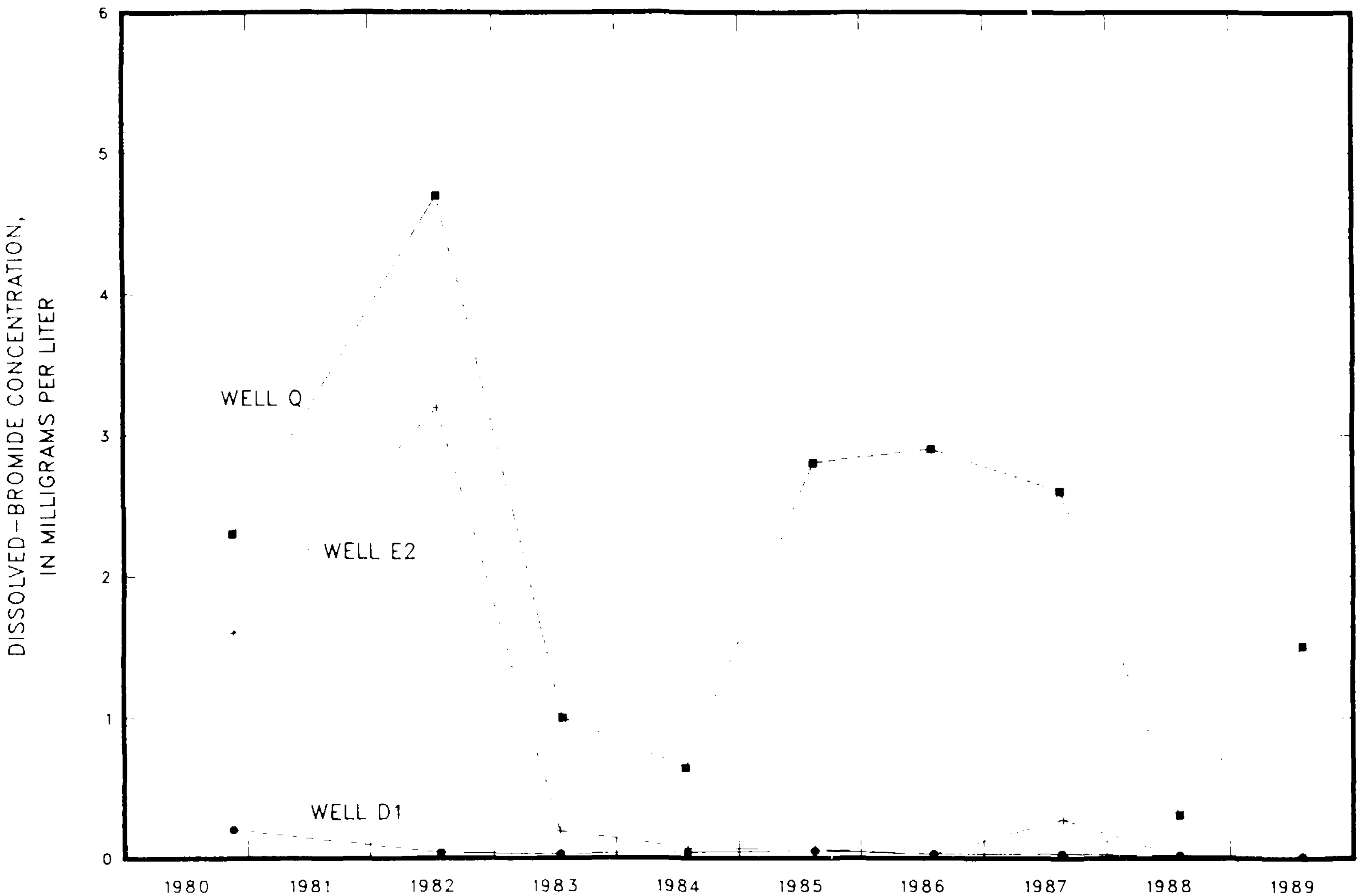


Figure 15.–Dissolved-bromide concentrations in water from wells D1, E2, and Q, 1980-89

Water from shallow wells downgradient from the landfill, such as well Q, had dissolved-bromide concentrations that fluctuated during the period of study (fig. 15). The fluctuations indicate the variability of dissolved-bromide concentrations at any point in the leachate plume. The fluctuations could be caused by patterns of precipitation and recharge near the landfill. Specifically, more water could percolate through the landfill refuse during wet periods than during dry periods. The percolating water would be in contact with refuse material that generally is unsaturated and, therefore, could contain more soluble materials, including bromide, than refuse below the water table. It is reasonable to assume that large concentrations of dissolved solids would be found in the ground water downgradient from the landfill after a prolonged wet period. Conversely, dissolved-solids concentrations would be small after a prolonged dry period if much of the soluble materials below the water table had already been removed.

Several wells near the landfill, such as E2, had water having dissolved-bromide concentrations that decreased during the study (fig. 15). The decrease in concentrations could indicate that the volume of soluble material in the landfill is decreasing or that recharge of fresh water from precipitation has depressed the zone of water containing bromide more deeply into the flow system. However, because of the fluctuation of dissolved-bromide concentrations in water from other wells downgradient from the landfill and because samples were collected only once each year, it is possible that dissolved-bromide concentrations in water from these wells also fluctuates, and the large concentrations were not detected because of the sampling frequency.

Movement of Water Containing Dissolved Bromide

The movement of water containing dissolved-bromide concentrations in the study area is characterized by downward vertical flow and by downgradient flow in the unconfined aquifer. The downward vertical flow is demonstrated by the relatively large concentrations detected in water from deep wells E3 and M1. Relatively large concentrations of dissolved bromide were detected in water from all wells at sites E and M at the beginning of the study period. During the study, dissolved-bromide concentrations decreased in water from shallow wells E1 and E2 and deep well M1. Dissolved-bromide concentrations in water from the deep well E3 and shallow well M2 remained relatively constant.

Downgradient flow of water containing dissolved bromide is shown by the relatively large concentrations in water from shallow wells that are downgradient from the landfill. The fluctuation of dissolved-bromide concentrations in water from these wells indicated that concentrations were variable in the leachate plume. Multiple-peak concentrations in water from shallow downgradient wells suggests that ground water having comparatively large dissolved-bromide concentrations may move in slugs in the direction of flow. The times of the peak concentrations for each well were compared to determine if the peaks corresponded to the downgradient distance of the well from the landfill. The relation between the time of each peak concentration and the downgradient distance was not well defined because of the multiple peaks and the sampling frequency; however, by using selected peak concentrations, it was possible to trace a slug of ground water having large dissolved-bromide concentrations moving in the direction of flow.

The rate of horizontal movement of dissolved bromide in the unconfined aquifer was estimated by means of selected peak concentrations of dissolved bromide in water from wells E1, Q, and I3. These wells are progressively downgradient from the landfill and form a line that is nearly parallel with the direction of ground-water flow (fig. 7). Well E1 had a dissolved-bromide concentration of 4.2 mg/L in 1982, well Q had a dissolved-bromide concentration of 2.9 mg/L in 1986, and well I3 had a dissolved-bromide concentration of 2.9 mg/L in 1988. Assuming that these peak concentrations represented a slug of ground water moving downgradient, the data could be used to estimate a rate of horizontal flow by dividing the distance between the wells by the length of time between peak concentrations. The rate of bromide movement was estimated to be 1.1 ft/d between wells E1 and Q, and 1.7 ft/d between wells Q and I3. The average rate of bromide movement over the entire distance from well E1 to I3 was estimated to be 1.2 ft/d.

The estimated rates of dissolved-bromide movement were compared to flow rates calculated according to Darcy's law by use of an assumed effective porosity of 25 percent, horizontal hydraulic conductivities of 80 and 400 ft/d, and the average horizontal hydraulic gradient between the wells. The results are listed in table 5. The values selected for hydraulic conductivity correspond to the average values calculated by Imbrigiotta and Martin (1981, p. 24) in sand and in sand and gravel from specific-capacity data of wells in the landfill area. The rates estimated from the time between peak concentrations are within the range of rates calculated with Darcy's law.

The estimated flow rates of ground water containing dissolved bromide are helpful in describing the movement of the bromide plume during the study period; however, caution should be used in attempting to project the arrival of a specific concentration of dissolved bromide at a specific well. For example, a rate of 1.2 ft/d over the distance from site I to site K would project that a dissolved-bromide concentration of about 2.0 mg/L that was detected in water from well I3 in 1980 would have reached site K in 1985. The largest dissolved-bromide concentration in water from shallow wells at site K in 1985 was 0.79 mg/L detected in water from well K1. Dissolved-bromide concentrations in water from shallow wells at site K ranged from not detected (less than 0.01 mg/L) to 0.9 mg/L during the study.

Table 5.--Rates of horizontal ground-water flow estimated from time between peak concentrations of dissolved bromide and rates calculated according to Darcy's law

Well pair	Distance (feet)	Average horizontal hydraulic gradient	Rate of ground-water movement from time between peak bromide concentrations (feet per day)	Rate of ground-water movement from Darcy's law and a hydraulic conductivity of 80 feet per day (feet per day)	Rate of ground-water movement from Darcy's law and a hydraulic conductivity of 400 feet per day (feet per day)
Well E1 to well Q	1,600	2.1×10^{-3}	1.1	0.7	3.4
Well Q to well I3	1,250	4.7×10^{-3}	1.7	1.5	7.5
Well E1 to well I3	2,750	3.4×10^{-3}	1.2	1.1	5.4

There are several explanations why larger concentrations of bromide have not been found at site K. Because samples were collected only once a year, it is possible that a larger concentration could have passed site K during the period between sample collections. The dissolved-bromide concentration of 0.9 mg/L indicates that well K1 is screened in or near the plume of bromide but may not intercept the area of largest concentration in the plume. Large concentrations of dissolved bromide may not reach site K because they may be attenuated by the physical processes of advection, diffusion, and dispersion.

SUMMARY

Ground-water data were collected in northwestern Elkhart County from 1980-89 for a monitoring program that was designed to provide hydrologic information to water-resources managers for use in evaluating the ground-water resources in the area. The data included water levels measured twice a year in 68 wells and water-quality analyses of water from 32 wells for each year except 1981.

The city of Elkhart obtains its public water supply from sand and gravel outwash deposits along the St. Joseph River. In the study area, the outwash deposits consist of two layers of sand and gravel separated by a discontinuous layer of silt and clay. The silt and clay layer divides the outwash into an upper unconfined aquifer and a lower confined aquifer. The saturated thickness of the outwash deposits ranges from about 40 ft to more than 450 ft.

Flow in the aquifers is primarily horizontal and toward the streams. Near the streams, ground-water levels are higher than the stage of the stream, indicating that ground water discharges to the streams. No large differences in ground-water-flow patterns were determined during the study. Measured ground-water levels ranged from about 6 ft above ground to about 29 ft below ground. The average depth to water was 10 ft. Water levels fluctuated seasonally and were generally highest in April and May and lowest in September and October. The average water-level fluctuation for the entire study period was 4.8 ft. Water levels in the confined aquifer were generally higher than water levels in the unconfined aquifer except near areas of pumping. Horizontal and vertical hydraulic gradients were steepest near the streams and areas of pumping.

Ground-water samples collected during the study had a median specific conductance of 516 μS/cm, a median ph of 7.6, a median alkalinity concentration of 216 mg/L, and a median dissolved-bromide concentration of 0.08 mg/L. Comparison of wells grouped according to their depth and position in relation to the closed industrial landfill, and the ground-water-flow system indicates that there is not much difference in water from shallow wells upgradient from the landfill and deep wells for the measured physical properties and chemical constituents. Water from shallow wells downgradient from the landfill had larger specific-conductance values, alkalinity, and dissolved-bromide concentrations, and smaller pH values than water from shallow wells upgradient from the landfill and deep wells.

The distribution of dissolved-bromide concentrations in ground water in the study area was used to estimate the extent of the landfill's effect on water quality. Relatively large concentrations of dissolved bromide were detected in water from deep wells near the landfill, indicating that water containing dissolved bromide had moved vertically downward in the aquifer beneath the landfill. The distribution of water containing relatively large concentrations of dissolved bromide indicates the presence of a leachate plume that extends south of the landfill at least to site K. Although dissolved-bromide concentrations in water samples from the same well varied for different sampling periods, the distribution of water containing dissolved bromide did not change substantially during the study period.

Concentrations of dissolved bromide fluctuated in water from shallow wells downgradient from the landfill. The time of occurrence of selected peak concentrations of dissolved bromide in water from shallow wells downgradient from the landfill was used to estimate rates of horizontal flow of water in the unconfined aquifer. The rates ranged from 1.1 to 1.7 ft/d. The estimated flow rates were in the range of rates calculated according to Darcy's law and the average horizontal hydraulic gradient between wells.

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Table 2.--Ground-water levels measured in northwestern Elkhart County and summary statistics, 1980-89

[All water-level altitudes in feet above sea level]

Well 15S		Well 15D		Well 17S		Well 17D		Well 20	
Date measured	Water-level altitude	Date measured	Water-level altitude	Date measured	Water-level altitude	Date measured	Water-level altitude	Date measured	Water-level altitude
12/11/80	742.63	12/11/80	742.64	05/18/82	725.64	04/25/83	730.91	12/11/80	741.45
05/13/81	743.20	05/13/81	743.14	04/21/83	724.54	10/27/83	730.66	05/13/81	742.68
09/17/81	744.56	09/17/81	744.57	10/27/83	722.04	04/18/84	730.57	09/23/81	742.65
05/03/82	743.76	05/03/82	743.78	04/18/84	725.63	10/25/84	729.77	05/07/82	743.78
04/18/83	743.26	04/18/83	743.30	10/25/84	722.22	04/16/85	732.07	04/21/83	743.22
10/26/83	741.96	10/26/83	741.45	04/16/85	725.74	11/11/85	729.55	10/26/83	740.61
04/18/84	742.25	04/18/84	741.85	11/11/85	725.54	04/17/86	728.44	04/17/84	742.39
10/25/84	742.10	10/25/84	742.07	04/17/86	725.60	10/01/86	728.18	10/24/84	742.26
04/11/85	743.41	04/11/85	743.60	10/01/86	725.99	04/28/87	727.35	04/16/85	744.19
11/11/85	741.07	11/11/85	741.09	04/28/87	725.35	10/22/87	727.63	11/08/85	740.38
04/17/86	742.13	04/17/86	742.16	10/22/87	725.37	04/05/88	729.13	04/17/86	742.24
09/30/86	741.79	10/01/86	741.79	04/05/88	725.96	10/12/88	728.15	10/01/86	742.35
04/27/87	741.24	04/27/87	741.95	10/12/88	725.54	04/20/89	729.44	04/23/87	742.25
10/20/87	740.33	10/20/87	740.29	04/20/89	725.95	10/17/89	728.77	10/22/87	740.47
03/28/88	740.41	03/28/88	740.43	10/17/89	725.57			03/30/88	742.05
10/12/88	739.89	10/12/88	739.79					10/11/88	740.91
04/20/89	741.68	04/20/89	741.57					04/19/89	742.97
10/17/89	741.26	10/17/89	741.24					10/17/89	741.98
Number of measurements =	18	Number of measurements =	18	Number of measurements =	15	Number of measurements =	14	Number of measurements =	18
Mean =	742.05	Mean =	742.04	Mean =	725.11	Mean =	729.33	Mean =	742.16
Median =	742.03	Median =	741.90	Median =	725.57	Median =	729.28	Median =	742.26
Minimum =	739.89	Minimum =	739.79	Minimum =	722.04	Minimum =	727.35	Minimum =	740.38
Maximum =	744.56	Maximum =	744.57	Maximum =	725.99	Maximum =	732.07	Maximum =	744.19

Table 2.--Ground-water levels measured in northwestern Elkhart County and summary statistics, 1980-89--Continued

Well 22		Well 23S		Well 23D		Well 29S		Well 29D	
Date measured	Water-level altitude	Date measured	Water-level altitude	Date measured	Water-level altitude	Date measured	Water-level altitude	Date measured	Water-level altitude
12/11/80	730.15	12/04/80	742.21	12/04/80	745.58	11/20/80	757.90	11/20/80	758.46
12/12/80	729.96	12/12/80	742.36	05/11/81	746.27	05/12/81	759.50	05/12/81	760.10
05/13/81	731.28	05/11/81	742.71	09/16/81	746.81	09/18/81	759.40	09/21/81	760.07
05/19/81	731.13	05/19/81	742.52	05/03/82	747.27	05/04/82	760.83	05/04/82	761.62
09/29/81	729.94	09/16/81	742.10	04/19/83	746.29	08/03/82	759.44	08/03/82	760.11
05/17/82	729.45	09/28/81	741.48	10/14/83	745.31	04/19/83	759.72	04/19/83	760.21
04/18/83	730.32	05/03/82	742.16	04/17/84	746.01	07/27/83	758.53	07/27/83	759.11
10/14/83	729.04	04/19/83	742.19	10/23/84	745.65	10/14/83	757.18	10/14/83	757.87
04/17/84	730.86	10/14/83	741.58	04/10/85	747.53	04/17/84	759.45	04/17/84	759.93
10/23/84	730.13	04/17/84	742.10	11/07/85	745.04	07/24/84	758.73	07/24/84	759.21
04/09/85	729.34	10/23/84	741.22	04/14/86	745.83	10/23/84	757.83	10/23/84	758.36
11/07/85	729.33	04/10/85	742.60	09/30/86	746.30	04/10/85	761.64	04/10/85	762.27
04/14/86	729.58	11/07/85	740.71	04/21/87	745.95	08/20/85	757.53	08/20/85	758.02
09/30/86	729.35	04/14/86	740.83	10/21/87	745.18	11/07/85	756.89	11/07/85	757.35
04/22/87	730.37	09/30/86	742.09	04/05/88	745.96	04/14/86	759.37	04/14/86	760.00
10/21/87	728.78	04/21/87	742.03	10/10/88	745.23	07/30/86	759.51	07/30/86	760.05
04/05/88	730.56	10/21/87	741.64	04/18/89	746.08	09/30/86	758.37	09/30/86	758.72
10/10/88	728.90	04/05/88	741.91	10/10/89	744.48	04/21/87	758.92	04/21/87	759.43
04/21/89	729.71	10/10/88	741.55			08/21/87	757.65	08/21/87	758.12
10/09/89	729.05	04/18/89	742.83			10/21/87	757.18	10/21/87	757.60
		10/09/89	741.90			04/05/88	759.05	04/05/88	759.62
						08/09/88	757.40	08/09/88	757.78
						10/10/88	756.79	10/10/88	757.32
						04/17/89	759.36	04/17/89	760.04
						08/08/89	758.34	08/11/89	758.93
						10/09/89	758.25	10/09/89	758.83

	Well 22	Well 23S	Well 23D	Well 29S	Well 29D
Number of measurements =	20	21	18	26	26
Mean =	729.86	741.94	745.93	758.64	759.20
Median =	729.82	742.09	745.96	758.63	759.16
Minimum =	728.78	740.71	744.48	756.79	757.32
Maximum =	731.28	742.83	747.53	761.64	762.27

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Table 2.--Ground-water levels measured in northwestern Elkhart County and summary statistics, 1980-89--Continued

Well 30S		Well 30D		Well 31		Well 34S		Well 34D	
Date measured	Water-level altitude	Date measured	Water-level altitude	Date measured	Water-level altitude	Date measured	Water-level altitude	Date measured	Water-level altitude
12/11/80	742.63	12/11/80	742.64	12/09/80	757.16	12/11/80	769.67	12/11/80	770.12
05/13/81	743.20	05/13/81	743.14	05/18/81	758.86	05/15/81	770.93	05/15/81	771.46
09/17/81	744.56	09/17/81	744.57	09/22/81	758.19	05/07/82	771.45	05/07/82	772.60
05/03/82	743.76	05/03/82	743.78	05/11/82	759.70	04/21/83	771.24	04/21/83	772.03
04/18/83	743.26	04/18/83	743.30	08/06/82	758.84	10/17/83	768.49	10/17/83	769.38
10/26/83	741.96	10/26/83	741.45	04/19/83	759.80	04/18/84	770.76	04/18/84	771.27
04/18/84	742.25	04/18/84	741.85	07/27/83	757.87	10/24/84	769.90	10/24/84	770.43
10/25/84	742.10	10/25/84	742.07	10/26/83	757.58	04/10/85	771.55	04/10/85	772.63
04/11/85	743.41	04/11/85	743.60	04/19/84	758.41	11/07/85	768.38	11/07/85	769.07
11/11/85	741.07	11/11/85	741.09	07/25/84	757.85	04/15/86	769.95	04/15/86	770.72
04/17/86	742.13	04/17/86	742.16	10/25/84	758.41	10/02/86	769.38	10/02/86	770.11
09/30/86	741.79	10/01/86	741.79	04/18/85	760.46	04/22/87	769.31	04/22/87	770.30
04/27/87	741.24	04/27/87	741.95	08/20/85	756.73	10/20/87	768.37	10/20/87	768.59
10/20/87	740.33	10/20/87	740.29	11/11/85	756.29	04/04/88	770.33	04/04/88	770.85
03/28/88	740.41	03/28/88	740.43	04/16/86	757.91	10/11/88	768.18	10/11/88	768.93
10/12/88	739.89	10/12/88	739.79	07/31/86	759.00	04/18/89	770.27	04/18/89	771.13
04/20/89	741.68	04/20/89	741.57	10/02/86	757.31	10/10/89	768.78	10/10/89	769.58
10/17/89	741.26	10/17/89	741.24	04/21/87	757.23				
				08/18/87	755.61				
				10/21/87	756.21				
				04/04/88	758.18				
				08/04/88	756.65				
				10/10/88	756.56				
				04/18/89	758.82				
				08/02/89	757.73				
				10/17/89	758.60				
Number of measurements =	18	Number of measurements =	18	Number of measurements =	26	Number of measurements =	17	Number of measurements =	17
Mean =	742.05	Mean =	742.04	Mean =	757.92	Mean =	769.82	Mean =	770.54
Median =	742.03	Median =	741.90	Median =	757.89	Median =	769.90	Median =	770.43
Minimum =	739.89	Minimum =	739.79	Minimum =	755.61	Minimum =	768.18	Minimum =	768.59
Maximum =	744.56	Maximum =	744.57	Maximum =	760.46	Maximum =	771.55	Maximum =	772.63

Table 2.--Ground-water levels measured in northwestern Elkhart County and summary statistics, 1980-89--Continued

Well 35S		Well 35D		Well 41S		Well 41D		Well 48	
Date measured	Water-level altitude	Date measured	Water-level altitude	Date measured	Water-level altitude	Date measured	Water-level altitude	Date measured	Water-level altitude
12/05/80	765.33	12/05/80	765.24	11/20/80	772.99	11/20/80	773.26	12/10/80	757.99
05/12/81	766.95	05/12/81	767.27	05/19/81	775.31	05/19/81	775.55	05/15/81	758.73
09/21/81	766.74	09/21/81	767.16	09/18/81	775.05	09/18/81	775.32	09/22/81	757.63
05/07/82	768.01	05/07/82	768.39	05/04/82	776.69	05/04/82	776.95	05/07/82	758.58
04/19/83	767.47	04/19/83	767.79	08/06/82	775.08	08/06/82	776.08	04/21/83	758.66
10/14/83	764.53	10/14/83	765.21	04/19/83	775.28	04/19/83	775.55	10/17/83	756.26
04/17/84	767.38	04/17/84	767.29	07/28/83	773.53	07/28/83	776.76	04/18/84	758.09
10/23/84	765.93	10/23/84	766.37	10/14/83	772.10	10/14/83	772.06	10/24/84	757.77
04/10/85	768.92	04/10/85	769.16	04/17/84	774.91	04/17/84	774.67	04/10/85	759.43
11/07/85	764.92	11/07/85	765.38	07/25/84	773.84	07/25/84	774.10	11/08/85	756.38
04/14/86	766.65	04/14/86	766.98	10/23/84	773.61	10/23/84	773.65	04/15/86	757.48
09/30/86	765.80	09/30/86	766.31	04/10/85	777.20	04/10/85	777.44	10/02/86	757.40
04/22/87	766.11	04/22/87	766.40	08/22/85	772.38	08/20/85	773.42	04/22/87	757.33
10/21/87	764.93	10/21/87	765.33	11/07/85	772.17	11/07/85	772.36	10/20/87	756.30
04/04/88	766.69	04/04/88	766.98	04/14/86	774.86	04/14/86	775.07	04/04/88	758.24
10/10/88	765.05	10/10/88	765.16	07/30/86	776.58	07/30/86	774.20	10/11/88	756.62
04/18/89	767.06	04/18/89	767.38	09/30/86	773.06	09/30/86	773.58	04/18/89	757.93
10/09/89	765.67	10/09/89	766.01	04/28/87	774.16	04/21/87	774.09	10/10/89	756.71
				08/21/87	772.54	08/21/87	772.68		
				10/22/87	772.01	10/22/87	772.20		
				04/05/88	774.55	04/05/88	774.60		
				08/10/88	771.74	08/10/88	771.87		
				10/10/88	771.64	10/10/88	771.78		
				04/17/89	774.93	04/17/89	774.96		
				08/08/89	773.53	08/11/89	773.47		
				10/09/89	773.34	10/09/89	773.50		

Well 35S	Well 35D	Well 41S	Well 41D	Well 48
Number of measurements = 18	Number of measurements = 18	Number of measurements = 26	Number of measurements = 26	Number of measurements = 18
Mean = 766.34	Mean = 766.66	Mean = 773.96	Mean = 774.20	Mean = 757.64
Median = 766.38	Median = 766.69	Median = 773.72	Median = 774.10	Median = 757.70
Minimum = 764.53	Minimum = 765.16	Minimum = 771.64	Minimum = 771.78	Minimum = 756.26
Maximum = 768.92	Maximum = 769.16	Maximum = 777.20	Maximum = 777.44	Maximum = 759.43

Table 2.--Ground-water levels measured in northwestern Elkhart County and summary statistics, 1980-89--Continued

Well 49		Well 51		Well 52		Well A1		Well A2	
Date measured	Water-level altitude	Date measured	Water-level altitude	Date measured	Water-level altitude	Date measured	Water-level altitude	Date measured	Water-level altitude
12/09/80	758.16	12/11/80	731.04	12/10/80	759.43	12/09/80	762.12	12/09/80	762.13
05/15/81	759.28	05/13/81	733.59	05/12/81	761.22	05/15/81	763.00	05/15/81	762.98
09/23/81	758.35	09/17/81	732.13	09/21/81	760.83	09/23/81	762.05	09/23/81	761.98
05/15/82	759.29	05/03/82	733.30	05/06/82	762.46	05/11/82	762.86	05/11/82	762.80
04/21/83	759.49	04/21/83	732.61	04/19/83	761.73	04/21/83	763.32	04/25/83	762.19
10/26/83	757.14	07/27/83	731.24	10/17/83	758.91	10/26/83	761.65	10/26/83	762.03
04/18/84	758.76	10/26/83	731.26	10/25/84	760.66	04/18/84	762.56	04/18/84	762.51
10/25/84	758.24	04/18/84	731.79	10/10/85	763.52	10/25/84	763.31	10/25/84	763.27
04/18/85	759.64	07/25/84	731.43	11/07/85	758.66	04/18/85	763.18	04/18/85	763.17
11/11/85	757.22	10/24/84	732.21	04/10/86	760.96	11/08/85	760.86	11/08/85	760.77
04/17/86	758.09	04/11/85	733.78	09/30/86	760.06	04/17/86	761.95	04/17/86	761.86
10/02/86	758.02	08/21/85	729.16	04/21/87	760.55	09/30/86	761.98	09/30/86	761.82
04/23/87	758.02	04/17/86	733.00	10/21/87	758.81	04/23/87	761.90	04/23/87	761.85
10/20/87	756.54	08/06/86	732.89	04/05/88	761.03	10/20/87	760.68	10/20/87	760.62
03/31/88	758.63	10/01/86	732.18	10/10/88	758.65	03/31/88	762.60	03/31/88	762.51
10/11/88	757.11	04/22/87	733.59	04/18/89	761.36	10/11/88	761.05	10/11/88	761.01
04/20/89	758.63	08/19/87	732.26	10/09/89	760.21	04/21/89	761.57	04/21/89	761.97
10/10/89	758.05	10/19/87	730.60			10/10/89	760.73	10/10/89	761.10
		03/28/88	733.11						
		08/09/88	729.75						
		10/10/88	732.48						
		04/21/89	733.50						
		08/04/89	732.73						
Number of measurements = 18		Number of measurements = 23		Number of measurements = 17		Number of measurements = 18		Number of measurements = 18	
Mean =	758.26	Mean =	732.16	Mean =	760.53	Mean =	762.08	Mean =	762.03
Median =	758.20	Median =	732.26	Median =	760.66	Median =	762.02	Median =	762.00
Minimum =	756.54	Minimum =	729.16	Minimum =	758.65	Minimum =	760.68	Minimum =	760.62
Maximum =	759.64	Maximum =	733.78	Maximum =	763.52	Maximum =	763.32	Maximum =	763.27

Table 2.--Ground-water levels measured in northwestern Elkhart County and summary statistics, 1980-89--Continued

Well B1		Well B2		Well B3		Well B4		Well C1	
Date measured	Water-level altitude	Date measured	Water-level altitude	Date measured	Water-level altitude	Date measured	Water-level altitude	Date measured	Water-level altitude
12/09/80	755.87	12/09/80	755.71	12/09/80	755.82	12/09/80	755.70	12/09/80	755.06
05/18/81	757.31	05/18/81	757.05	05/18/81	757.18	05/18/81	757.07	05/18/81	756.46
09/24/81	756.48	09/24/81	756.24	09/24/81	756.39	09/24/81	756.30	09/24/81	755.70
05/13/82	757.64	05/13/82	757.35	05/13/82	757.52	05/13/82	757.46	05/13/82	756.82
04/20/83	757.86	04/20/83	757.59	04/20/83	757.78	04/20/83	757.70	04/20/83	756.91
10/27/83	755.43a	10/27/83	754.84	10/27/83	756.07	10/27/83	754.98	10/27/83	754.39
04/19/84	756.86	04/19/84	756.62	04/19/84	756.77	04/19/84	756.70	04/19/84	756.03
10/24/84	756.89	10/24/84	756.69	10/24/84	756.76	10/24/84	756.70	10/24/84	755.99
04/17/85	758.38	04/17/85	758.05	04/17/85	758.25	04/17/85	758.19	04/17/85	757.50
11/12/85	754.62	11/12/85	754.69	11/12/85	754.69	11/12/85	754.58	11/12/85	753.89
04/16/86	756.17	04/16/87	755.92	04/16/86	756.05	04/16/86	755.96	04/17/86	--- b
10/01/86	755.72	10/01/86	759.23	10/01/86	755.65	10/01/86	755.50		
04/23/87	756.04	04/23/87	755.84	04/23/87	755.99	04/23/87	755.89		
10/20/87	754.48	10/20/87	754.23	10/20/87	754.37	10/20/87	754.27		
04/05/88	756.67	04/05/88	756.56	04/06/88	757.20	04/05/88	756.52		
10/11/88	754.96	10/11/88	754.75	10/11/88	754.86	10/11/88	754.77		
04/19/89	756.95	04/19/89	756.67	04/19/89	756.92	04/19/89	756.76		
10/10/89	754.97	10/10/89	754.80	10/10/89	754.95	10/10/89	754.81		
Number of measurements =	18	Number of measurements =	18	Number of measurements =	18	Number of measurements =	18	Number of measurements =	10
Mean =	756.29	Mean =	756.27	Mean =	756.29	Mean =	756.10	Mean =	755.88
Median =	756.32	Median =	756.40	Median =	756.23	Median =	756.13	Median =	756.01
Minimum =	754.48	Minimum =	754.23	Minimum =	754.37	Minimum =	754.27	Minimum =	753.89
Maximum =	758.38	Maximum =	759.23	Maximum =	758.25	Maximum =	758.19	Maximum =	757.50

Table 2.--Ground-water levels measured in northwestern Elkhart County and summary statistics, 1980-89--Continued

Well C3		Well C4		Well D1		Well D2		Well D3	
Date measured	Water-level altitude	Date measured	Water-level altitude	Date measured	Water-level altitude	Date measured	Water-level altitude	Date measured	Water-level altitude
12/09/80	755.33	12/09/80	754.05	11/18/80	754.41	11/18/80	754.39	11/18/80	754.35
05/18/81	756.76	05/18/81	755.37	05/15/81	755.79	05/15/81	755.72	05/15/81	755.68
09/24/81	756.02	09/24/81	754.69	09/23/81	755.25	09/23/81	755.19	09/23/81	755.19
05/13/82	757.16	05/13/82	755.53	05/11/82	756.66	05/11/82	756.62	05/11/82	756.59
04/20/83	757.37	04/20/83	755.54	07/28/82	756.33	07/28/82	756.10	07/29/82	756.06
10/27/83	754.64	10/27/83	752.93	04/21/83	756.67	08/05/82	755.91	04/21/83	756.60
04/19/84	756.39	04/19/84	754.62	07/20/83	754.96	04/21/83	756.62	07/20/83	754.87
10/24/84	756.31	10/24/84	754.92	10/26/83	754.12	07/20/83	754.87	10/26/83	754.20
04/17/85	757.84	04/17/85	755.91	04/18/84	755.69	10/26/83	754.44	04/18/84	755.61
11/12/85	754.25	11/12/85	752.93	07/31/84	754.66	04/18/84	755.61	07/31/84	754.58
04/16/86	--- b	04/16/87	--- b	10/25/84	755.38	07/31/84	754.60	10/25/84	755.35
				04/18/85	757.39	10/25/84	755.33	04/18/85	757.32
				08/14/85	753.65	04/18/85	757.31	08/14/85	753.41
				11/08/85	753.13	08/14/85	753.04	11/08/85	753.04
				04/17/86	754.74	11/08/85	753.06	04/17/86	754.70
				08/05/86	755.22	04/17/86	754.71	08/05/86	755.46
				09/30/86	754.20	08/05/86	760.14	09/30/86	754.02
				04/23/87	754.62	09/30/86	754.03	04/23/87	754.70
				08/20/87	756.47	04/23/87	754.70	08/20/87	753.10
				10/20/87	753.13	08/20/87	753.14	10/20/87	753.09
				03/31/88	754.92	10/20/87	753.04	03/31/88	754.76
				08/04/88	753.12	03/31/88	754.76	08/04/88	753.02
				10/11/88	753.52	08/04/88	753.03	10/11/88	753.45
				04/20/89	754.03	10/11/88	753.46	04/20/89	755.59
				08/02/89	752.63	04/20/89	755.59	08/02/89	754.15
				10/10/89	751.72	08/02/89	754.16	10/10/89	753.27
						10/10/89	753.27		
Number of measurements =	10	Number of measurements =	10	Number of measurements =	26	Number of measurements =	27	Number of measurements =	26
Mean =	756.21	Mean =	754.65	Mean =	754.71	Mean =	754.92	Mean =	754.70
Median =	756.35	Median =	754.80	Median =	754.70	Median =	754.71	Median =	754.70
Minimum =	754.25	Minimum =	752.93	Minimum =	751.72	Minimum =	753.03	Minimum =	753.02
Maximum =	757.84	Maximum =	755.91	Maximum =	757.39	Maximum =	760.14	Maximum =	757.32

Table 2.--Ground-water levels measured in northwestern Elkhart County and summary statistics, 1980-89--Continued

Well E1, EH(8)		Well E2		Well E3		Well F1		Well F2	
Date measured	Water-level altitude	Date measured	Water-level altitude	Date measured	Water-level altitude	Date measured	Water-level altitude	Date measured	Water-level altitude
11/19/80	752.27	11/19/80	752.27	11/19/80	752.31	12/09/80	750.29	12/09/80	746.42
05/13/81	754.18	05/13/81	754.05	05/13/81	753.59	05/13/81	751.70	05/13/81	745.39
09/24/81	753.34	09/24/81	753.51	09/24/81	753.36	09/22/81	751.68	09/22/81	745.71
05/13/82	754.72	05/13/82	755.09	05/13/82	754.71	05/10/82	753.61	05/10/82	747.10
04/20/83	754.84	07/20/82	755.00	07/20/82	754.85	07/30/82	752.83	07/30/82	746.63
04/20/83	754.85c	04/20/83	755.09	04/21/83	754.78	04/20/83	752.76	04/20/83	748.01
07/19/83	752.92	07/19/83	752.99	07/19/83	752.95	07/27/83	751.07	07/21/83	745.65
10/26/83	751.86c	10/26/83	751.73	10/26/83	751.77	10/26/83	749.81	10/26/83	747.[illegible]
04/18/84	753.34c	04/18/84	754.37	04/18/84	753.39	04/17/84	751.17	04/17/84	746.92
08/01/84	752.44	08/01/84	752.52	08/01/84	752.47	04/17/85	750.93	08/01/84	745.66
10/25/84	752.29c	10/25/84	753.45	10/25/84	753.40	08/21/85	749.06	10/24/84	746.72
04/17/85	755.46c	04/17/85	755.63	04/17/85	755.43	11/08/85	748.35	04/11/85	747.94
08/14/85	751.62	08/14/85	751.61	08/14/85	751.57	04/15/86	750.10	08/21/85	743.69
11/08/85	750.88c	11/08/85	750.94	11/08/85	750.95	08/01/86	751.67	11/08/85	743.80
04/16/86	752.72c	04/16/86	752.76	04/16/86	752.74	09/30/86	750.21	04/15/86	744.32
08/07/86	753.68	08/07/86	753.43	08/07/86	753.27	04/21/87	749.91	08/01/86	745.49
09/30/86	752.34c	09/30/86	752.71	09/30/86	752.36	08/18/87	748.91	09/30/86	744.55
04/23/87	752.56c	04/23/87	752.59	04/23/87	752.51	10/21/87	748.48	04/21/87	746.64
08/25/87	751.16	08/25/87	749.26	08/25/87	751.17	03/30/88	750.74	08/18/87	743.32
10/20/87	750.70c	10/20/87	750.87	10/20/87	750.91	08/03/88	750.23	10/21/87	745.75
03/30/88	752.61c	03/30/88	752.68	03/30/88	752.49	10/11/88	750.26	03/30/88	746.57
08/10/88	751.67	08/10/88	751.67	08/10/88	751.69	04/20/89	752.01	08/03/88	740.59
10/11/88	751.59c	10/11/88	751.58	10/11/88	751.62	08/09/89	749.64	10/11/88	745.98
04/19/89	753.78c	04/19/89	753.96	04/19/89	753.87	10/17/89	748.32	04/20/89	748.24d
08/10/89	752.25	08/10/89	752.39	08/10/89	752.31			08/09/89	742.81
10/10/89	751.43c	10/10/89	751.56	10/10/89	751.45			10/17/89	743.50
Number of measurements = 26		Number of measurements = 26		Number of measurements = 26		Number of measurements = 24		Number of measurements = 26	
Mean =	752.75	Mean =	752.84	Mean =	752.77	Mean =	750.57	Mean =	745.55
Median =	752.50	Median =	752.70	Median =	752.50	Median =	750.28	Median =	745.73
Minimum =	750.70	Minimum =	749.26	Minimum =	750.91	Minimum =	748.32	Minimum =	740.59
Maximum =	755.46	Maximum =	755.63	Maximum =	755.43	Maximum =	753.61	Maximum =	748.24

Table [illegible] ter levels measured in northwestern Elkhart County and [illegible]mmary statistics, 1980-89--Continued

Well F5		Well G1		Well G3		Well H2		Well H4	
Date measured	Water-level altitude	Date measured	Water-level altitude	Date measured	Water-level altitude	Date measured	Water-level altitude	Date measured	Water-level altitude
12/09/80	744.28	12/10/80	748.79	12/10/80	742.32	11/20/80	744.79	11/20/80	748.66
05/13/81	743.78	05/13/81	749.95	05/13/81	740.04	12/11/80	745.18	12/11/80	748.71
09/22/81	744.12	09/22/81	749.96	09/22/81	740.55	05/13/81	747.30	05/13/81	748.97
05/10/82	744.96	05/10/82	750.96f	05/10/82	743.12g	09/21/81	746.13	09/21/81	748.56
07/30/82	744.53	04/19/83	751.06	04/19/83	745.53	05/10/82	746.90	05/10/82	749.44
04/20/83	745.91	07/21/83	749.51	07/21/83	742.22	04/20/83	747.35	04/20/83	750.09
07/21/83	743.64	10/26/83	748.63	10/26/83	744.77	04/17/84	746.65	10/26/83	749.28
10/26/83	745.48	04/17/84	749.83	04/17/84	743.76	10/24/84	746.51	04/17/84	749.43
04/17/85	744.93	07/26/84	748.84	07/26/84	741.25	04/11/85	747.91	10/24/84	748.62
08/01/84	743.52	10/24/84	748.78	10/24/84	742.12	11/08/85	745.31	04/11/85	750.14
10/24/84	744.60	04/11/85	751.54	04/11/85	742.74	04/15/86	745.99	11/08/85	747.17
04/11/85	745.25	08/16/85	747.85	08/16/85	740.40	10/01/86	746.30	04/15/86	747.68
08/21/85	741.16	11/08/85	747.63	11/08/85	737.02	04/22/87	746.18	10/01/86	747.69
11/08/85	741.73	04/15/86	749.11	04/15/86	736.54	10/11/88	745.60	04/22/87	748.51
04/15/86	742.33	07/31/86	749.77	07/31/86	738.14	04/19/89	746.81	10/11/88	747.84
08/01/86	742.81	09/30/86	748.94	09/30/86	737.04	10/17/89	745.00	04/19/89	748.56
09/30/86	742.09	04/21/87	749.02	04/21/87	740.39			10/17/89	746.74
04/21/87	743.61	08/18/87	747.68	08/18/87	736.97				
08/18/87	740.93	10/21/87	747.72	10/21/87	741.03				
10/21/87	743.12	04/04/88	749.78	04/04/88	741.09				
03/30/88	743.61	08/05/88	747.90	08/05/88	740.82				
08/03/88	737.70	10/11/88	748.59	10/11/88	741.67				
10/11/88	742.73	04/19/89	750.40	04/19/89	738.16				
04/20/89	745.63e	08/08/89	747.06	08/08/89	733.84				
08/09/89	740.16	10/17/89	741.63	10/17/89	736.94				
10/17/89	741.34								
Number of measurements = 26		Number of measurements = 25		Number of measurements = 25		Number of measurements = 16		Number of measurements = 17	
Mean =	743.23	Mean =	748.84	Mean =	740.34	Mean =	746.24	Mean =	748.59
Median =	743.61	Median =	748.94	Median =	740.82	Median =	746.24	Median =	748.62
Minimum =	737.70	Minimum =	741.63	Minimum =	733.84	Minimum =	744.79	Minimum =	746.74
Maximum =	745.91	Maximum =	751.54	Maximum =	745.53	Maximum =	747.91	Maximum =	750.14

Table 2.--Ground-water levels measured in northwestern Elkhart County and summary statistics, 1980-89--Continued

Well I1		Well I2		Well I3		Well J1		Well J2	
Date measured	Water-level altitude	Date measured	Water-level altitude	Date measured	Water-level altitude	Date measured	Water-level altitude	Date measured	Water-level altitude
12/10/80	744.03	12/10/80	743.15	12/10/80	743.16	11/12/80	740.77	11/20/80	740.74
05/13/81	745.30	05/13/81	744.38	05/13/81	744.39	05/13/81	745.14	05/13/81	745.16
09/24/81	744.90	09/24/81	744.32	09/24/81	744.33	09/22/81	744.93	09/22/81	744.90
05/11/82	745.04	05/11/82	744.97	05/11/82	745.00	05/10/82	745.16	07/29/82	746.26
07/22/82	745.65	07/22/82	745.88	07/22/82	745.73	07/29/82	745.21	04/20/83	744.23
04/20/83	745.00	04/20/83	744.85	04/20/83	744.74	04/20/83	744.26	07/26/83	744.12
07/22/83	742.95	07/22/83	743.68	07/22/83	743.70	07/26/83	744.13	10/27/83	740.85
10/27/83	741.96	10/27/83	742.39	10/27/83	741.97	10/27/83	740.70	04/17/84	741.36
04/18/84	743.87	04/18/84	743.16	04/18/84	743.17	04/17/84	741.34	07/26/84	740.06
07/26/84	742.49	07/26/84	742.82	07/26/84	742.83	07/26/84	740.04	10/24/84	742.42
10/25/84	743.70	10/25/84	744.05	10/25/84	743.89	10/24/84	742.46	04/11/85	744.30
04/17/85	745.41	04/17/85	745.09	04/17/85	745.07	04/11/85	744.19	08/15/85	741.81
08/13/85	741.71	08/13/85	741.26	08/13/85	742.27	08/15/85	741.80	11/08/85	741.03
11/08/85	741.47	11/08/85	741.62	11/08/85	741.64	11/08/85	741.00	04/15/86	742.87
04/15/86	742.99	04/15/86	743.32	04/15/86	743.36	04/15/86	742.86	07/31/86	745.45
08/06/86	743.56	08/06/86	744.68	08/06/86	744.52	07/31/86	744.80	10/01/86	743.97
09/30/86	742.80	08/12/86	744.35	09/30/86	743.94	10/01/86	743.62	04/27/87	742.09
04/23/87	742.76	09/30/86	744.01	04/23/87	743.20	04/27/87	742.05	08/20/87	740.55n
08/19/87	741.56	04/23/87	743.14	08/19/87	742.36	08/20/87	741.55	10/22/87	Dry
10/22/87	741.70	08/19/87	742.39	10/22/87	741.59	10/22/87	737.79	03/30/88	741.24
03/28/88	743.86	10/22/87	741.58	03/28/88	743.07	03/30/88	741.28	08/03/88	741.92
08/02/88	741.55	03/28/88	743.07	08/02/88	742.37	08/03/88	741.95	10/11/88	741.16
10/11/88	742.08	08/22/88	742.19	10/11/88	742.61	10/11/88	741.20	04/20/89	744.45
04/20/89	745.01	10/11/88	742.59	04/20/89	744.50	04/20/89	744.52	08/01/89	Dry
08/03/89	743.86	04/20/89	744.54	08/03/89	743.99	08/01/89	737.50	10/12/89	741.58
10/12/89	743.92	08/03/89	743.98	10/12/89	743.41	10/12/89	741.60		
		10/12/89	743.34						
Number of measurements =	26	Number of measurements =	27	Number of measurements =	26	Number of measurements =	26	Number of measurements =	23
Mean =	743.43	Mean =	743.51	Mean =	743.49	Mean =	742.38	Mean =	742.72
Median =	743.63	Median =	743.34	Median =	743.38	Median =	742.00	Median =	742.09
Minimum =	741.47	Minimum =	741.26	Minimum =	741.59	Minimum =	737.50	Minimum =	740.06
Maximum =	745.65	Maximum =	745.88	Maximum =	745.73	Maximum =	745.21	Maximum =	746.26

Table 2.--Ground-water levels measured in northwestern Elkhart County and summary statistics, 1980-89--Continued

Well J3		Well K1		Well K2		Well K3		Well L1	
Date measured	Water-level altitude	Date measured	Water-level altitude	Date measured	Water-level altitude	Date measured	Water-level altitude	Date measured	Water-level altitude
11/20/80	739.74	12/10/80	736.78	12/10/80	736.72	12/10/80	727.65	12/09/80	744.56
05/13/81	738.47	05/13/81	737.96	05/13/81	737.87	05/13/81	732.94	05/13/81	745.91
09/22/81	739.22	09/23/81	738.27	09/23/81	737.70	09/23/81	732.24	09/24/81	745.49
05/10/82	739.72	05/10/82	738.13	05/10/82	738.03	05/10/82	722.77	05/11/82	746.70
07/29/82	737.27	07/21/82	738.25	04/18/83	737.53	08/05/82	719.98	04/21/83	746.29
04/20/83	741.03	04/18/83	737.56	07/25/83	734.71	04/18/83	722.29	10/26/83	743.80
07/26/83	737.02	07/25/83	734.83	10/17/83	735.69	07/25/83	718.42	04/18/84	745.09
10/27/83	740.46	10/17/83	737.45	04/18/84	736.25	10/17/83	734.80	10/24/84	745.30
04/17/84	740.30	04/18/84	736.28	07/27/84	734.62	04/18/84	729.59	04/16/85	746.62
07/26/84	737.95	07/27/84	734.73	10/25/84	736.90	07/27/84	718.05	11/08/85	743.07
10/24/84	739.16	10/25/84	736.70	04/11/85	737.98	10/25/84	719.24	04/17/86	745.00
04/11/85	739.98	12/06/84	735.69	08/15/85	733.73	12/06/84	720.01	10/02/86	746.04
08/15/85	734.02	04/11/85	738.02	11/11/85	735.21	04/11/85	721.42	04/23/87	744.67
11/08/85	734.63	08/15/85	733.71	04/17/86	736.44	08/15/85	719.57	10/22/87	743.17
04/15/86	734.28	11/11/85	735.01	08/07/86	737.11	11/11/85	718.73	03/30/88	745.11
07/31/86	735.56	04/17/86	736.52	10/01/86	737.83	04/17/86	719.67	10/11/88	743.75
10/01/86	734.92	08/07/86	737.25	04/27/87	736.23	08/07/86	719.85	04/19/89	745.91
04/27/87	737.66	10/01/86	736.68	08/19/87	734.99	10/01/86	724.57	10/12/89	744.77
08/20/87	734.06	04/27/87	736.33	10/22/88	734.03	04/27/87	719.06		
10/22/87	738.00	08/19/87	734.85	03/30/88	737.00	08/19/87	717.92		
03/30/88	737.27	10/22/87	734.12	08/02/88	734.31	10/22/87	718.51		
08/03/88	735.20	03/30/88	737.18	10/11/88	735.35	03/30/88	722.71		
10/11/88	735.71	08/02/88	734.57	04/20/89	737.75	08/02/88	720.21		
04/20/89	736.61	10/11/88	735.45	08/03/89	737.10	10/11/88	718.52		
08/01/89	732.36	04/20/89	737.90	10/12/89	736.93	04/20/89	730.71		
10/12/89	736.21	08/03/89	737.21			08/03/89	720.64		
		10/12/89	737.05			10/12/89	730.53		
Number of measurements = 26		Number of measurements = 27		Number of measurements = 25		Number of measurements = 27		Number of measurements = 18	
Mean =	737.18	Mean =	736.46	Mean =	736.32	Mean =	722.99	Mean =	745.07
Median =	737.27	Median =	736.70	Median =	736.72	Median =	720.21	Median =	745.10
Minimum =	732.36	Minimum =	733.71	Minimum =	733.73	Minimum =	717.92	Minimum =	743.07
Maximum =	741.03	Maximum =	738.27	Maximum =	738.03	Maximum =	734.80	Maximum =	746.70

Table 2.--Ground-water levels measured in northwestern Elkhart County and summary statistics, 1980-89--Continued

Well L2		Well L4		Well M1		Well M[illegible]		Well [illegible]	
Date measured	Water-level altitude	Date measured	Water-level altitude	Date measured	Water-level altitude	Date measured	Water-level altitude	Date measured	Water-level altitude
12/09/80	746.26	12/09/80	744.52	11/19/80	753.46	11/19/80	755.05	11/18/80	752.20
05/13/81	748.60i	05/13/81	745.83	05/18/81	754.43	05/18/81	754.46	05/18/81	754.08
09/24/81	747.22	09/24/81	745.42	09/24/81	753.69	09/24/81	753.74	09/24/81	753.20
05/11/82	747.97	05/11/82	746.13	05/13/82	755.06	05/13/82	757.15	05/11/82	754.41
04/21/83	748.07	04/21/83	746.19	08/06/82	755.20	08/06/82	755.06	07/20/82	754.75
10/26/83	745.27	10/26/83	743.62	04/20/83	755.13	04/20/83	755.14	04/29/83	754.52
04/18/84	746.91	04/18/84	745.02	07/28/83	753.07	07/28/83	753.01	07/20/83	752.70
10/24/84	747.04	10/24/84	746.27	10/26/83	752.0[illegible]	10/26/83	752.10	10/26/83	751.57
04/16/85	748.43	04/16/85	746.64	04/18/84	753.07	04/18/84	753.74	04/18/84	753.09
11/08/85	744.83	11/08/85	743.13	08/02/84	752.80	08/02/84	75[illegible].76	07/30/84	752.[illegible]
04/17/86	746.80	04/17/86	744.95	10/25/84	753.77	10/25/84	753.75	10/24/84	753.[illegible]
10/02/88	746.60	10/02/86	744.93	04/17/85	755.85	04/17/85	755.83	04/16/85	754.97
04/23/87	746.51	04/23/87	744.77	08/21/85	751.84	08/21/85	75[illegible].01	08/20/85	751.57
10/22/87	744.98	10/22/87	743.15	11/08/85	751.31	11/08/85	751.37	11/08/85	750.89
03/30/88	746.96	03/30/88	745.10	04/17/86	753.05	04/17/86	753.03	04/16/86	75[illegible]
10/11/88	745.59	10/11/88	743.67	08/05/86	753.58	08/05/86	75[illegible]	08/05/86	[illegible]
04/19/89	747.83	04/19/89	745.83	09/30/86	752.71	09/30/86	752.70	09/30/86	752.[illegible]
10/12/89	746.69	10/12/89	744.67	04/23/87	753.00	04/23/87	752.87	04/23/87	75[illegible].39
				08/25/87	751.52	08/25/87	752.34	08/20/87	751.27
				10/20/87	751.26	10/20/87	751.15	10/20/87	750.47
				03/30/88	753.10	03/30/88	753.05	03/30/88	752.65
				08/09/88	751.93	08/09/88	751.84	08/04/88	751.46
				10/11/88	751.96	10/11/88	751.93	10/11/88	751.57
				04/19/89	754.10	04/19/89	754.15	04/20/89	753.65
				08/10/89	752.67	08/10/89	752.59	08/03/89	753.40
				10/10/89	751.76	10/10/89	751.78	10/12/89	751.75
Number of measurements =	18	Number of measurements =	18	Number of measurements =	26	Number of measurements =	26	Number of measurements =	2[illegible]
Mean =	746.8[illegible]	Mean =	744.99	Mean =	753.15	Mean =	753.3[illegible]	Mean =	75[illegible]
Median =	746.86	Median =	744.98	Median =	753.06	Median =	753.0[illegible]	Median =	75[illegible].65
Minimum =	744.83	Minimum =	743.13	Minimum =	751.26	Minimum =	751.15	Minimum =	750.47
Maximum =	748.60	Maximum =	746.64	Maximum =	755.85	Maximum =	757.15	Maximum =	754.97

Table 2.--Ground-water levels measured in northwestern Elkhart County and summary statistics, 1980-89--Continued

Well O		Well P		Well Q		Well R1		Well R2	
Date measured	Water-level altitude	Date measured	Water-level altitude	Date measured	Water-level altitude	Date measured	Water-level altitude	Date measured	Water-level altitude
11/18/80	751.71	11/18/80	751.87	11/18/80	748.63	12/02/80	721.50	12/02/80	722.28
05/18/81	754.39	05/18/81	753.64	05/13/81	750.49	12/12/80	722.40	12/12/80	722.86
09/23/81	753.77	09/23/81	752.95	09/23/81	749.86	05/19/81	722.47	05/19/81	723.52
05/11/82	755.46	05/11/82	754.51	05/11/82	751.12	09/30/81	721.99	09/29/81	722.79
08/03/82	754.71	07/19/82	755.55	07/21/82	752.87	05/17/82	722.25	05/17/82	722.82
04/21/83	755.36	04/21/83	754.43	04/20/83	750.97	04/18/83	722.68	04/19/83	724.28
07/26/83	753.19	07/26/83	752.40	07/27/83	749.29	10/14/83	721.28	10/14/83	722.04
10/26/83	752.20	10/26/83	751.41	10/26/83	747.75	04/18/84	722.28	04/17/84	723.39
04/18/84	753.93	04/18/84	752.99	04/18/84	749.40	10/25/84	722.34	10/23/84	722.77
07/31/84	752.96	07/31/84	752.12	07/25/84	748.87	04/16/85	722.57	04/09/85	726.36
10/25/84	753.76	10/25/84	752.96	10/25/84	749.66	11/11/85	720.35	11/07/85	722.43
04/18/85	756.12	04/16/85	755.20	04/17/85	751.58	04/17/86	721.71	04/14/86	722.68
08/19/85	752.24	08/13/85	751.13	08/13/85	748.35	10/01/86	721.30	09/30/86	722.86
11/11/85	751.48	11/08/85	750.45	11/08/85	747.26	04/28/87	721.28	04/22/87	722.85
04/17/86	753.08	04/17/86	752.26	04/15/86	749.10	10/25/87	718.56	10/19/87	721.69
08/05/86	752.56	08/06/86	752.87	08/01/86	750.37	04/05/88	721.78	04/05/88	723.23
09/30/86	752.64	09/30/86	751.89	09/30/86	749.45	10/11/88	720.55	10/10/88	722.09
04/23/87	752.97	04/23/87	752.16	04/23/87	748.76	04/20/89	722.83	04/17/89	723.03
08/20/87	751.50	08/20/87	750.81	08/18/87	747.85	10/17/89	721.00	10/09/89	722.10
10/20/87	751.36	10/20/87	750.41	10/21/87	747.20				
03/31/88	753.11	03/31/88	752.41	03/30/88	749.00				
08/04/88	751.76	08/03/88	751.21	08/04/88	748.19				
10/11/88	752.02	10/11/88	751.31	10/11/88	748.13				
04/20/89	754.17	04/20/89	753.47	04/20/89	750.39				
08/02/89	752.80	08/01/89	752.21	08/03/89	749.50				
10/10/89	751.60	10/10/89	750.83	10/12/89	748.37				
Number of measurements =	26	Number of measurements =	26	Number of measurements =	26	Number of measurements =	19	Number of measurements =	19
Mean =	753.11	Mean =	752.44	Mean =	749.32	Mean =	721.64	Mean =	722.95
Median =	752.96	Median =	752.24	Median =	749.20	Median =	721.78	Median =	722.82
Minimum =	751.36	Minimum =	750.41	Minimum =	747.20	Minimum =	718.56	Minimum =	721.69
Maximum =	756.12	Maximum =	755.55	Maximum =	752.87	Maximum =	722.83	Maximum =	726.36

Table 2.--Ground-water levels measured in northwestern Elkhart County and summary statistics, 1980-89--Continued

Well R3		Well R6		Well R11	
Date measured	Water-level altitude	Date measured	Water-level altitude	Date measured	Water-level altitude
12/02/80	732.16	12/02/80	765.04	12/09/80	759.87
12/12/80	732.27	12/12/80	765.04	05/20/81	761.33
05/19/81	732.77	05/20/81	765.37	09/29/81	760.15
09/29/81	732.20	09/29/81	765.73	05/17/82	760.46
05/17/82	732.44	05/17/82	765.64	04/19/83	760.69
04/18/83	732.65	04/19/83	765.72	10/17/83	759.00
10/14/83	731.42	10/17/83	764.68	04/17/84	760.30
04/17/84	732.23	04/17/84	765.37	10/24/84	761.06
10/23/84	732.11	10/23/84	765.56	04/10/85	761.40
04/09/85	732.99	04/10/85	766.41	11/11/85	759.58
11/07/85	731.65	10/07/85	764.99	04/14/86	759.89
04/14/86	732.11	04/14/86	765.10	09/30/86	760.07
09/30/86	732.41	09/30/86	765.70	04/21/87	759.84
04/22/87	732.81	04/22/87	765.28	10/20/87	759.29
10/19/87	732.32	10/21/87	764.84	04/04/88	760.11
04/05/88	733.51	04/04/88	765.33	10/10/88	759.26
10/10/88	--- b	10/10/88	764.65	04/18/89	760.19
		04/18/89	765.38	10/10/89	759.45
		10/09/89	765.37		
Number of measurements = 16		Number of measurements = 19		Number of measurements = 18	
Mean =	732.38	Mean =	765.33	Mean =	760.11
Median =	732.30	Median =	765.37	Median =	760.09
Minimum =	731.42	Minimum =	764.65	Minimum =	759.00
Maximum =	733.51	Maximum =	766.41	Maximum =	761.40

(a) Recorded in field notes as 745.43.
(b) Well destroyed.
(c) Maximum daily altitude from water-level recorder.
(d) Measurement assigned to well F5 in field notes.
(e) Measurement assigned to well F2 in field notes.
(f) Measurement assigned to well G3 in field notes.
(g) Measurement assigned to well G1 in field notes.
(h) Recorded in field notes as 750.55.
(i) Recorded in field notes as 738.60.

Table 3.--Water-quality analyses of ground water in northwestern Elkhart County, 1980-89

[µS/cm, microsiemens per centimeter at 25 °C; °C, degrees Celsius; mg/L, milligram per liter; $CaCO_3$, calcium carbonate; ---, no data; <, less than]

Well number	Site identification number	Sample date	Specific conductance (µS/cm) (00095)[1]	pH (standard units) (00400)[1]	Water temperature (°C) (00010)[1]	Oxygen, dissolved (mg/L) (00300)[1]	Alkalinity (mg/L as $CaCO_3$) (00410)[1]	Bromide, dissolved (mg/L) (71870)[1]
29S	414258085531801	11/20/80	490	7.7	12.5	< 0.1	144	0.10
		08/03/82	476	8.0	12.5	.4	120	.04
		07/27/83	463	8.0	13.0	.7	120	.06
		07/24/84	480	7.7	13.0	1.4	132	.04
		08/20/85	522	7.6	13.0	.8	128	.07
		07/30/86	501	7.7	16.0	1.9	135	.04
		08/21/87	503	7.6	16.0	.9	128	.04
		08/09/88	516	7.5	15.5	1.3	120	.04
		08/08/89	519	7.8	15.0	.1	143	.03
29D	414258085531802	11/20/80	510	7.5	12.0	< 0.1	266	.2
		08/03/82	500	7.8	13.5	< 0.1	260	.03
		07/27/83	489	7.6	13.0	.2	270	.02
		07/24/84	507	7.4	14.0	.7	262	.02
		08/20/85	505	7.4	13.0	.6	251	.86
		07/30/86	499	7.5	14.0	1.8	251	.03
		08/21/87	502	7.5	15.5	1.0	260	.01
		08/09/88	517	7.5	15.0	.4	264	.03
		08/11/89	500	7.5	15.5	.2	257	.01
31	414259086000301	12/09/80	351	7.8	10.5	2.5	144	.10
		08/06/82	371	7.8	11.5	2.1	130	.04
		07/27/83	348	8.0	13.0	4.2	130	.04
		07/25/84	360	7.7	13.0	3.8	130	.03
		08/20/85	350	7.7	12.5	4.6	125	.04
		07/31/86	348	8.0	16.5	3.9	135	.03
		08/18/87	398	8.0	14.0	5.6	152	.02
		08/04/88	472	7.8	16.5	6.0	136	.03
		08/02/89	434	7.8	15.0	5.8	154	.02
41S	414532085521602	11/20/80	290	8.2	11.0	6.1	72	.10
		08/06/82	301	8.4	11.5	4.6	80	.03
		07/28/83	308	8.2	13.0	4.7	100	.05
		07/25/84	336	8.1	11.5	4.6	104	.04
		08/22/85	386	7.9	16.0	4.2	101	.06
		07/30/86	324	8.2	13.0	5.3	101	.70
		08/21/87	323	8.1	13.0	5.0	98	.03
		08/10/88	386	8.1	12.5	4.0	100	.02
		08/08/89	356	8.2	12.0	4.3	116	.01

Table 3.--Water-quality analyses of ground water in northwestern Elkhart County, 1980-89--Continued

Well number	Site identification number	Sample date	Specific conductance (µS/cm) (00095)[1]	pH (standard units) (00400)[1]	Water temperature (°C) (00010)[1]	Oxygen, dissolved (mg/L) (00300)[1]	Alkalinity (mg/L as $CaCO_3$) (00410)[1]	Bromide, dissolved (mg/L) (71870)[1]
41D	414532085521601	11/20/80	550	7.4	11.0	< 0.1	295	< 0.01
		08/06/82	500	7.7	12.5	< .1	270	.03
		07/28/83	503	7.7	13.0	.1	280	.03
		07/25/84	516	7.5	12.0	.6	277	.02
		08/20/85	524	7.5	13.5	.9	275	.01
		07/30/86	515	7.6	11.5	.6	274	.04
		08/21/87	516	7.5	12.5	1.0	279	.03
		08/10/88	541	7.4	13.5	.8	267	.02
		08/11/89	525	7.7	21.0	.4	202	.03
51	414125085591101	07/25/84	668	7.3	12.5	.5	230	.07
		08/21/85	623	7.2	17.5	1.3	226	.09
		08/06/86	623	7.2	18.5	3.4	224	.03
		08/19/87	623	7.0	20.0	2.3	214	.07
		08/09/88	523	7.0	20.0	.1	130	.07
		08/04/89	523	7.0	20.0	.1	149	.05
D1	414235086001501	11/18/80	500	7.7	12.0	3.6	166	.20
		07/28/82	430	7.9	13.0	5.6	140	.04
		07/20/83	336	8.0	14.0	7.2	100	.03
		07/31/84	395	7.6	14.0	3.7	120	.04
		08/14/85	379	7.9	14.5	6.6	117	.05
		08/05/86	396	7.6	20.0	5.8	122	.03
		08/20/87	424	7.8	17.0	6.3	126	.03
		08/04/88	462	8.0	16.0	7.4	126	.02
		08/02/89	335	7.9	16.5	7.1	105	.01
D2	414235086001502	11/18/80	420	7.6	11.5	< .1	202	.20
		08/05/82	402	7.9	11.0	< .1	190	.03
		07/20/83	392	7.9	11.0	< .1	230	.03
		07/31/84	395	7.6	13.5	4.6	174	.06
		08/14/85	410	7.7	12.5	1.1	173	.05
		08/05/86	417	7.8	13.0	2.0	173	.03
		08/20/87	430	7.6	14.5	.3	173	.03
		08/04/88	455	7.6	15.0	3.0	203	.03
		08/02/89	433	7.7	13.0	.7	212	.03

Table 3.--Water-quality analyses of ground water in northwestern Elkhart County, 1980-89--Continued

Well number	Site identification number	Sample date	Specific conductance (µS/cm) (00095)[1]	pH (standard units) (00400)[1]	Water temperature (°C) (00010)[1]	Oxygen, dissolved (mg/L) (00300)[1]	Alkalinity (mg/L as $CaCO_3$) (00410)[1]	Bromide, dissolved (mg/L) (71870)[1]
D3	414235086001503	11/18/80	500	7.6	11.0	< 0.1	166	0.40
		07/29/82	479	8.0	10.5	< .1	160	.11
		07/20/83	471	8.0	10.5	< .1	180	.09
		07/31/84	422	7.7	12.5	2.4	152	.08
		08/14/85	479	7.7	12.0	.9	145	.07
		08/05/86	489	7.8	13.0	1.8	153	.08
		08/20/87	445	7.8	15.5	2.0	155	.03
		08/04/88	540	7.7	13.5	2.0	179	.06
		08/02/89	528	7.8	13.0	1.2	180	27
E1	414446086002501	11/19/80	980	7.6	12.0	.2	382	3.0
		07/20/82	1,040	7.8	11.5	< .1	420	4.2
		07/19/83	1,020	7.6	11.5	< .1	410	2.3
		08/01/84	952	6.9	13.0	.5	376	2.2
		08/14/85	995	7.3	13.5	.6	362	1.3
		08/07/86	1,070	7.3	15.0	1.1	384	1.2
		08/25/87	1,070	7.3	13.0	.4	385	.61
		08/10/88	1,030	7.1	15.0	1.8	384	.40
		08/10/89	998	7.5	14.0	.7	347	.26
E2	414446086002502	11/19/80	1,000	7.4	13.0	< .1	389	1.6
		07/20/82	1,700	7.3	15.0	.2	320	3.2
		07/19/83	770	7.1	15.0	.1	330	.19
		08/01/84	365	7.0	14.0	1.0	135	.07
		08/14/85	310	7.4	16.5	1.5	125	.06
		08/07/86	255	6.7	16.5	1.7	116	.03
		08/25/87	248	7.4	14.5	1.3	92	.27
		08/10/88	248	7.1	16.0	1.5	87	< .01
		08/10/89	300	7.1	16.0	.4	123	< .01
E3	414446086002503	11/19/80	890	7.7	11.5	< .1	432	3.3
		07/20/82	767	8.1	11.0	< .1	370	2.6
		07/19/83	868	7.7	11.0	< .1	420	1.3
		08/01/84	883	7.0	12.5	.9	398	2.5
		08/14/85	994	7.6	13.0	.6	362	2.6
		08/07/86	988	7.5	13.0	1.7	405	3.0
		08/25/87	980	7.5	12.5	.4	415	2.7
		08/10/88	1,020	7.5	13.5	.4	403	3.1
		08/10/89	1,130	7.5	14.0	.3	516	2.9

Table 3.--Water-quality analyses of ground water in northwestern Elkhart County, 1980-89--Continued

Well number	Site identification number	Sample date	Specific conduc- tance (µS/cm) (00095)[1]	pH (standard units) (00400)[1]	Water temper- ature (°C) (00010)[1]	Oxygen, dissolved (mg/L) (00300)[1]	Alkalinity (mg/L as $CaCO_3$) (00410)[1]	Bromide, dissolved (mg/L) (71870)[1]
F1	414210085595601	12/09/80	639	7.6	11.0	< 0.1	180	0.10
		07/30/82	773	7.5	13.0	< .1	250	.39
		07/27/83	665	7.7	13.0	.1	200	.17
		08/21/85	692	7.6	17.0	.4	172	.11
		08/01/86	678	8.0	21.5	1.1	184	.01
		08/18/87	798	7.3	17.5	.1	250	.17
		08/03/88	826	7.4	17.5	.4	257	.11
		08/09/89	497	7.5	17.5	.4	251	.08
F2	414210085595602	12/09/80	368	7.7	11.0	< .1	216	.10
		07/30/82	381	7.9	11.0	< .1	190	.02
		07/21/83	373	7.9	11.0	< .1	200	.01
		08/01/84	398	7.3	14.0	.7	189	.01
		08/21/85	388	7.6	15.5	.8	195	< .01
		08/01/86	364	7.8	15.0	2.0	188	< .01
		08/18/87	387	7.9	15.0	.3	184	.01
		08/03/88	410	7.8	16.0	2.2	186	.02
		08/09/89	393	7.8	14.0	.4	187	.04
F5	414210085595605	12/09/80	392	7.6	11.0	< .1	216	.10
		07/30/82	459	7.9	11.0	< .1	210	.06
		07/21/83	464	8.0	11.0	< .1	230	.04
		08/01/84	478	7.3	13.5	.8	202	.08
		08/21/85	408	7.7	15.0	1.2	192	.04
		08/01/86	459	7.8	16.0	1.8	229	.07
		08/18/87	474	7.9	15.0	1.8	223	.05
		08/03/88	558	7.8	19.5	1.3	220	.11
		08/09/89	466	7.4	14.5	.1	234	.08
G1	414235085592901	12/10/80	410	7.5	11.0	< .1	180	.10
		07/21/83	447	7.9	11.5	< .1	180	.03
		07/26/84	448	7.5	12.0	.9	173	.03
		08/16/85	480	7.7	13.0	.9	176	.05
		07/31/86	471	7.9	12.5	.9	180	.04
		08/18/87	518	7.8	15.0	1.0	194	.02
		08/05/88	532	7.6	18.0	1.6	194	.04
		08/08/89	490	7.8	12.5	.1	194	.01

Table 3.--Water-quality analyses of ground water in northwestern Elkhart County, 1980-89--Continued

Well number	Site identification number	Sample date	Specific conductance (µS/cm) (00095)[1]	pH (standard units) (00400)[1]	Water temperature (°C) (00010)[1]	Oxygen, dissolved (mg/L) (00300)[1]	Alkalinity (mg/L as $CaCO_3$) (00410)[1]	Bromide, dissolved (mg/L) (71870)[1]
G3	414235085592903	12/10/80	446	7.7	11.0	< 0.1	216	0.10
		07/21/83	516	8.0	11.0	< .1	220	.05
		07/26/84	475	7.8	11.5	5.5	220	.04
		08/16/85	520	7.7	13.5	.9	209	.06
		07/31/86	528	7.7	12.0	4.6	220	.04
		08/18/87	545	7.8	15.5	1.3	230	.04
		08/05/88	496	7.8	13.5	4.0	220	.03
		08/08/89	525	7.9	12.5	.2	230	.04
I1	414148086001801	12/10/80	417	7.5	11.5	< .1	252	.10
		07/22/82	398	8.1	11.5	< .1	210	.03
		07/22/83	391	8.0	11.5	< .1	220	.02
		07/26/84	404	7.8	15.0	6.1	215	.05
		08/13/85	413	7.7	16.0	1.2	195	< .01
		08/06/86	400	7.8	14.0	1.8	230	.02
		08/19/87	414	8.0	17.5	1.0	215	< .01
		08/02/88	443	8.0	15.5	.6	207	.01
		08/03/89	417	7.9	14.5	.2	241	.02
I2	414148086001802	12/10/80	526	7.6	12.5	< .1	180	.30
		07/22/82	440	7.5	16.5	.4	160	.10
		07/22/83	414	7.6	19.5	4.4	150	.04
		07/26/84	445	7.4	17.0	5.7	167	.06
		08/13/85	534	7.4	20.0	6.2	153	.08
		08/12/86	290	7.1	22.0	6.0	174	.10
		08/19/87	600	7.4	19.5	5.8	178	.07
		08/02/88	653	7.4	20.0	6.6	181	.08
		08/03/89	586	7.5	20.5	.1	180	.05
I3	414148086001803	12/10/80	769	7.5	12.5	< .1	396	2.2
		07/22/82	855	7.6	12.5	< .1	440	3.2
		07/22/83	869	7.5	12.5	< .1	460	2.4
		07/26/84	1,060	7.2	15.0	1.0	429	2.4
		08/13/85	1,010	7.3	18.0	1.7	437	2.6
		08/06/86	1,050	7.3	15.0	1.4	497	2.7
		08/19/87	1,240	7.3	16.0	.6	585	2.7
		08/02/88	1,350	7.4	16.5	.6	624	2.9
		08/03/89	1,070	7.3	17.0	.4	534	2.1

Table 3.--Water-quality analyses of ground water in northwestern Elkhart County, 1980-89--Continued

Well number	Site identification number	Sample date	Specific conductance (µS/cm) (00095)[1]	pH (standard units) (00400)[1]	Water temperature (°C) (00010)[1]	Oxygen, dissolved (mg/L) (00300)[1]	Alkalinity (mg/L as $CaCO_3$) (00410)[1]	Bromide, dissolved (mg/L) (71870)[1]
J1	414155085594101	11/20/80	480	7.4	13.5	< 0.1	202	0.10
		07/29/82	804	7.6	12.0	< .1	330	1.7
		07/26/83	828	7.7	13.0	< .1	320	1.1
		07/26/84	613	7.3	17.0	.6	209	.15
		08/15/85	680	7.4	16.0	.7	209	.40
		07/31/86	569	7.6	18.5	.6	228	.06
		08/20/87	769	7.3	19.5	.6	309	.53
		08/03/88	966	7.3	17.0	.7	301	.85
		08/01/89	734	7.4	16.5	.3	216	.14
J2	414155085594102	11/20/80	710	7.2	15.0	7.0	252	.40
		07/29/82	581	7.5	15.0	.6	200	.08
		07/26/83	309	7.8	15.5	.3	150	.04
		07/26/84	606	7.5	16.5	7.9	153	.03
		08/15/85	879	6.9	17.5	4.6	368	.06
		07/31/86	996	6.8	22.5	2.8	420	.12
		08/20/87	942	6.7	23.0	3.5	376	.05
		08/03/88	895	6.9	20.0	7.0	386	.04
J3	414155085594103	11/20/80	400	7.6	13.5	.9	209	< .01
		07/29/82	399	8.0	12.5	< .1	210	.03
		07/26/83	441	8.0	12.5	< .1	230	.03
		07/26/84	452	7.6	14.5	.6	240	.05
		08/15/85	470	7.7	14.5	.7	240	.06
		07/31/86	455	7.7	15.0	1.8	235	.07
		08/20/87	511	7.5	21.0	1.0	232	.04
		08/03/88	491	7.6	18.0	2.4	232	.03
		08/01/89	464	7.6	14.5	.1	226	.04
K1	414125086000301	12/10/80	393	7.5	11.5	< .1	180	.30
		07/21/82	396	8.0	12.0	< .1	150	.73
		07/25/83	423	7.9	12.0	< .1	180	.77
		07/27/84	471	6.9	13.5	.7	201	.83
		12/06/84	400	7.0	14.0	---	---	.90
		08/15/85	414	7.9	14.0	1.0	187	.79
		08/07/86	516	7.5	13.0	1.8	209	.89
		08/19/87	555	7.7	15.0	3.5	210	.81
		08/02/88	606	7.7	16.0	1.7	225	.12
		08/03/89	586	7.9	16.5	.2	224	< .01

Table 3.--Water-quality analyses of ground water in northwestern Elkhart County, 1980-89--Continued

Well number	Site identification number	Sample date	Specific conductance (µS/cm) (00095)[1]	pH (standard units) (00400)[1]	Water temperature (°C) (00010)[1]	Oxygen, dissolved (mg/L) (00300)[1]	Alkalinity (mg/L as $CaCO_3$) (00410)[1]	Bromide, dissolved (mg/L) (71870)[1]
K2	414125086000302	12/10/80	394	7.5	11.0	< 0.1	216	0.40
		07/21/82	553	7.2	18.0	.1	210	.71
		07/25/83	604	7.5	14.0	.1	230	.61
		07/27/84	688	6.5	16.5	1.8	263	.25
		08/15/85	841	6.9	14.5	.9	279	.27
		08/07/86	775	7.0	14.5	1.7	280	.21
		08/19/87	786	6.9	18.0	4.0	284	.20
		08/02/88	999	7.4	18.5	1.1	255	.40
		08/03/89	819	7.1	16.0	.5	286	.22
K3	414125086000303	12/10/80	383	8.1	11.5	< .1	216	.20
		08/05/82	460	8.1	11.5	< .1	200	.11
		07/25/83	449	8.0	11.5	< .1	200	.11
		07/27/84	417	7.1	15.5	1.2	191	.04
		12/06/84	400	7.0	14.0	---	---	.13
		08/15/85	502	7.8	14.5	.6	187	.07
		08/07/86	433	7.7	13.0	1.5	190	.07
		08/19/87	412	7.8	16.5	4.0	188	.06
		08/02/88	479	7.8	16.0	.8	192	.08
		08/03/89	429	7.9	12.5	.2	215	.05
M1	414219086002501	11/19/80	1,000	7.6	12.5	< .1	346	2.6
		08/06/82	1,070	7.5	13.0	< .1	370	4.6
		07/28/83	913	7.4	14.0	.2	290	1.7
		08/02/84	878	6.8	13.0	.8	337	.70
		08/21/85	1,010	7.2	14.0	.7	334	.83
		08/05/86	874	7.9	13.0	2.5	335	1.3
		08/25/87	810	7.8	12.5	1.0	365	.38
		08/09/88	1,020	7.3	14.5	3.7	362	.31
		08/10/89	1,010	7.3	13.5	.2	322	.19
M2	414219086002502	11/19/80	2,200	6.8	12.5	< .1	1,000	3.8
		08/06/82	768	7.1	14.0	< .1	380	2.9
		07/28/83	380	7.1	15.0	.1	390	2.1
		08/02/84	1,140	6.4	13.0	.6	612	2.2
		08/21/85	1,210	7.0	13.5	.5	616	2.1
		08/05/86	1,150	7.0	12.5	2.0	590	2.7
		08/25/87	1,070	6.8	13.0	.2	542	2.0
		08/09/88	1,010	6.8	15.0	2.2	534	2.3
		08/10/89	1,010	6.9	13.5	.3	542	2.6

Table 3.--Water-quality analyses of ground water in northwestern Elkhart County, 1980-89--Continued

Well number	Site identification number	Sample date	Specific conductance (µS/cm) (00095)[1]	pH (standard units) (00400)[1]	Water temperature (°C) (00010)[1]	Oxygen, dissolved (mg/L) (00300)[1]	Alkalinity (mg/L as $CaCO_3$) (00410)[1]	Bromide, dissolved (mg/L) (71870)[1]
N	414214086003701	11/18/80	920	7.2	11.5	< 0.1	324	1.3
		07/20/82	1,050	7.5	13.5	< .1	350	1.9
		07/20/83	1,060	7.5	13.0	< .1	400	1.9
		07/30/84	1,250	6.8	12.0	.6	574	2.7
		08/20/85	1,390	7.2	12.5	.4	549	2.3
		08/05/86	1,210	7.3	13.5	1.5	534	1.7
		08/20/87	955	7.2	15.5	.2	270	.45
		08/04/88	854	7.6	16.0	2.6	170	.10
		08/03/89	784	7.4	13.5	.3	192	.13
O	414223086001301	11/18/80	550	7.5	12.5	.4	122	.10
		08/03/82	505	7.6	16.0	.2	120	.07
		07/26/83	478	7.7	14.5	.6	120	.06
		07/31/84	560	7.4	12.5	1.3	121	.05
		08/19/85	600	7.9	13.0	1.0	128	.08
		08/05/86	675	7.7	13.0	1.1	138	.04
		08/20/87	606	7.7	14.0	.4	145	.05
		08/04/88	601	7.9	16.5	5.0	137	.04
		08/02/89	674	7.7	13.5	.2	180	.04
P	414214086001301	11/18/80	1,580	7.0	10.5	1.1	893	1.9
		07/19/82	1,590	7.2	14.5	< .1	740	3.0
		07/28/83	308	8.2	13.0	4.7	100	2.7
		07/31/84	1,260	6.7	14.0	.8	717	1.1
		08/13/85	1,600	6.9	16.5	.9	697	.86
		08/06/86	1,420	7.1	13.0	1.5	670	.52
		08/20/87	1,660	7.0	15.5	.2	642	.35
		08/03/88	1,170	7.2	14.5	2.2	649	.29
		08/01/89	1,260	7.2	13.5	.6	558	.34
Q	414159086002201	11/18/80	1,010	7.3	12.5	< .1	504	2.3
		07/21/82	1,140	7.3	16.5	< .1	580	4.7
		07/27/83	1,170	7.4	14.0	.2	570	1.0
		07/25/84	1,380	7.1	14.0	.9	682	.64
		08/13/85	1,370	7.1	16.0	.7	669	2.8
		08/01/86	1,400	7.2	16.0	1.6	682	2.9
		08/18/87	1,400	7.2	16.0	.6	616	2.6
		08/04/88	1,230	7.3	16.0	2.2	428	.30
		08/03/89	1,140	7.0	19.5	.1	474	1.5

[1] Five-digit WATSTORE (U.S. Geological Survey) and STORET (U.S. Environmental Protection Agency) data-base parameter code.